PHILOSOPHICAL TRANSACTIONS,

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCIII.

PART II.

LONDON,

PRINTED BY W. BULMER AND CO. CLEVELAND-ROW, ST. JAMES'S;
AND SOLD BY G. AND W. NICOL, PALL-MALL, BOOKSELLERS TO HIS MAJESTY,
AND PRINTERS TO THE ROYAL SOCIETY.
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PHILOSOPHICAL TRANSACTIONS.

XI. *Account of some Experiments on the Descent of the Sap in Trees. In a Letter from* Thomas Andrew Knight, *Esq. to the Right Hon. Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read April 21, 1803.

MY DEAR SIR,

In a Memoir which I had the honour to present to you two years ago,* I related some experiments on trees, from which I inferred, that their sap, having been absorbed by the bark of the root, is carried up by the alburnum or white wood, of the root, the trunk, and the branches; that it passes through what are there called the central vessels, into the succulent part of the annual shoot, the leaf-stalk, and the leaf; and that it returns to the bark, through the returning vessels of the leaf-stalk. The principal object of this Paper is, to point out the causes of the descent of the sap through the bark, and the consequent formation of wood.

These causes appear to be, gravitation, motion communicated

* See Phil. Trans. for 1801, p. 333.

by winds or other agents, capillary attraction, and probably something in the conformation of the vessels themselves, which renders them better calculated to carry fluids in one direction than in another. I shall begin with a few observations on the leaf, from which all the descending fluids in the tree appear to be derived. This organ has much engaged the attention of naturalists, particularly of M. BONNET: but their experiments have chiefly been made on leaves severed from the tree; and, therefore, whatever conclusions have been drawn, stand on very questionable ground. The efforts which plants always make to turn the upper surfaces of their leaves to the light, have with reason induced naturalists to conclude, that each surface has a totally distinct office; and the following experiments tend strongly to support that conclusion.

I placed a small piece of plate glass under a large vine leaf, with its surface nearly parallel with that of the leaf; and, as soon as the glass had acquired the temperature of the house in which the vine grew, I brought the under surface of the leaf into contact with it, by means of a silk thread and a small wire, adapted to its form and size. Having retained the leaf in this position one minute, I removed it, and found the surface of the glass covered with a strong dew, which had evidently exhaled from the leaf. I again brought the leaf into contact with the glass, and, at the end of half an hour, found so much water discharged from the leaf, that it ran off the glass when held obliquely. I then inverted the position of the leaf, and placed its upper surface in contact with the glass: not the slightest portion of moisture now appeared, though the leaf was exposed to the full influence of the meridian sun. These experiments were repeated on many different leaves; and the result was, in

every instance, precisely the same. It seems, therefore, that in the vine, the perspiratory vessels are confined to the under surface of the leaf: and these, like the cutaneous lymphatics of the animal economy, are probably capable of absorbing moisture, when the plant is in a state to require it. The upper surface seems, from the position it always assumes, either formed to absorb light, or to operate by the influence of that body; and, if any thing exhale from it, it is probably vital air, or some other permanently elastic fluid. It nevertheless appears evident, in the experiments of BONNET, that this surface of the leaves of many plants, when detached from the tree, readily absorbs moisture.

Selecting two young shoots of the vine, growing perpendicularly against the back wall of my vinery, I bent them downwards, nearly in a perpendicular line, and introduced their succulent ends, as layers, into two pots, without wounding the stems, or depriving them of any portion of their leaves. In this position, these shoots, which were about four feet long, and sprang out of the principal stem about three feet from the ground, grew freely, and, in the course of the summer, reached the top of the house. As soon as their wood became sufficiently solid to allow me to perform the operation with safety, I made two circular incisions through the bark of the depending part of each shoot, at a small distance from each other, near the surface of the mould in the pots; and I wholly removed the bark between the incisions; thus cutting off all communication, through the bark, between the layers and the parent stems. Had the subjects of this experiment now retained their natural position, much new wood and bark would have been formed at the upper lip of the wounds, and none at all at the lower, as I

have ascertained by frequent experiment. The case was now different: much new bark and wood was generated on the lower lip of the wounds, become uppermost by the inverted position of the branches; and I have no doubt but that the new matter, thus deposited, owed its formation to a portion of sap, which descended by gravitation, from the leaves growing between the wounded parts and the principal stems.

The result of this experiment appears to point out one of the causes why perpendicular shoots grow with much greater vigour than others: they have probably a more perfect and more rapid circulation.

The effects of motion on the circulation of the sap, and the consequent formation of wood, I was best able to ascertain by the following expedient. Early in the spring of 1801, I selected a number of young seedling apple-trees, whose stems were about an inch in diameter, and whose height, between the roots and first branches, was between six and seven feet. These trees stood about eight feet from each other; and, of course, a free passage for the wind to act on each tree was afforded. By means of stakes and bandages of hay, not so tightly bound as to impede the progress of any fluid within the trees, I nearly deprived the roots and lower parts of the stems, of several trees, of all motion, to the height of three feet from the ground, leaving the upper parts of the stems and branches in their natural state. In the succeeding summer, much new wood accumulated, in the parts which were kept in motion by the wind; but the lower parts of the stems and roots increased very little in size. Removing the bandages from one of these trees in the following winter, I fixed a stake in the ground, about ten feet distant from the tree, on the east side of it; and I attached the

tree to the stake, at the height of six feet, by means of a slender pole about twelve feet long; thus leaving the tree at liberty to move towards the north and south, or, more properly, in the segment of a circle, of which the pole formed a radius; but in no other direction. Thus circumstanced, the diameter of the tree from north to south, in that part of its stem which was most exercised by the wind, exceeded that in the opposite direction, in the following autumn, in the proportion of thirteen to eleven.

These results appear to open an extensive and interesting field to our observation, where we shall find much to admire, in the means which nature employs to adapt the forms of its vegetable productions to every situation in which art or accident may deposit them. If a tree be placed in a high and exposed situation, where it is much kept in motion by winds, the new matter which it generates will be deposited chiefly in the roots and lower parts of the trunk; and the diameter of the latter will diminish rapidly in its ascent. The progress of the ascending sap will of course be impeded; and it will thence cause lateral branches to be produced, or will pass into those already existing. The forms of such branches will be similar to that of the trunk; and the growth of the insulated tree on the mountain will be, as we always find it, low and sturdy, and well calculated to resist the heavy gales to which its situation constantly exposes it.

Let another tree of the same kind be surrounded, whilst young, by others, and it will assume a very different form. It will now be deprived of a part of its motion, and another cause will operate: the leaves on the lateral branches will be partly deprived of light, and, as I have remarked in the last Paper I

had the honour to address to you, little alburnum will then be generated in those branches. Their vigour, of course, becomes impaired, and less sap is required to support their diminished growth: more, in consequence, remains for the leading shoots; these, therefore, exert themselves with increased energy; and the trees seem to vie with each other for superiority, as if endued with all the passions and propensities of animal life.

An insulated tree in a sheltered valley, will assume, from the foregoing causes, a form distinct from either of the preceding;* and its growth will be more or less aspiring, in proportion to the degree of protection it receives from winds, and its contiguity to elevated objects, by which its lower branches, during any part of the day, are shaded.

When a tree is wholly deprived of motion, by being trained to a wall, or when a large tree has been deprived of its branches, to be regrafted, it often becomes unhealthy, and not unfrequently perishes, apparently owing to the stagnation of the descending sap, under the rigid cincture of the lifeless external bark. I have, in the last two years, pared off this bark from some very old pear and apple-trees, which had been regrafted with cuttings from young seedling trees; and the effect pro-

* Not only the external form of the tree, but the internal character of the wood will be affected by the situation in which the tree grows; and hence, oak timber which grew in crowded forests, appears to have been mistaken, in old buildings, for Spanish chesnut. But I have found the internal organization of the oak and Spanish chesnut to be very essentially different. (See a magnified view of each in Plate IV.) The silver grain and general character of the oak and Spanish chesnut, are also so extremely dissimilar, that the two kinds of wood can only be mistaken for each other by very careless observers. Many pieces of wood found in the old buildings of London, and supposed to be Spanish chesnut, have been put into my hands; but they were all most certainly forest oak.

duced has been very extraordinary. More new wood has been generated in the old trunks, within the last two years, than in the preceding twenty years; and I attribute this to the facility of communication which has been restored between the leaves and the roots, through the inner bark. I have had frequent occasion to observe, that wherever the bark has been most reduced, the greatest quantity of wood has been deposited.

Other causes of the descent of the sap towards the root, I have supposed to be, capillary attraction, and something in the conformation of the vessels of the bark. The alburnum also appears, in my former experiments, to expand and contract very freely, under changes of temperature and of moisture; and the motion thus produced must be in some degree communicated to the bark, should the latter substance be in itself wholly inactive. I however consider gravitation as the most extensive and active cause of motion, in the descending fluids of trees; and I believe, that from this agent, vegetable bodies, like unorganized matter, generally derive, in a greater or less degree, the forms they assume; and probably it is necessary to the existence of trees that it should be so. For, if the sap passed and returned as freely in the horizontal and pendent, as in the perpendicular branch, the growth of each would be equally rapid, or nearly so: the horizontal branch would then soon extend too far from its point of suspension at the trunk of the tree, and thence must inevitably perish, by the compound ratio in which the powers of destruction, compared with those of preservation, would increase.

The principal office of the horizontal branch, in the greatest number of trees, is to nourish and support the blossoms, and the fruit or seed; and, as these give back little or nothing to the

parent tree, very feeble powers alone are wanted in the returning system. No power at all had been fatal; and powers sufficiently strong wholly to counteract the effects of gravitation, had probably been in a high degree destructive. And it appears to me by no means improbable, that the formation of blossoms may, in many instances, arise from the diminished action of the returning system in the horizontal or pendent branch.

I have long been disposed to believe the ascending fluids in the alburnum and central vessels, wherever found, to be everywhere the same; and that the leaf-stalk, the tendril of the vine, the fruit-stalk, and the succulent point of the annual shoot, might in some measure be substituted for each other; and experiment has proved my conjecture, in many instances, to be well founded. Leaves succeeded, and continued to perform their office, when grafted on the fruit-stalk, the tendril, and succulent shoot, of the vine; and the leaf-stalk, the tendril, and the fruit-stalk, alike supplied a branch grafted upon them with nourishment. But I did not succeed in grafting a fruit-stalk of the vine on the leaf-stalk, the tendril, or succulent shoot. My ill success, however, I here attribute solely to want of proper management; and I have little doubt of succeeding in future.

The young shoots of the vine, when grafted on the leaf-stalk, often grew to the length of nine or ten feet; and the leaf-stalk itself, to some distance below its juncture with the graft, was found, in the autumn, to contain a considerable portion of wood, in every respect similar to the alburnum in other parts of the tree.

The formation of alburnum in the leaf-stalk, seemed to point out to me the means of ascertaining the manner in which it is generated in other instances; and to that point my attention was in consequence attracted. Having grafted a great many

leaf-stalks with shoots of the vine, I examined, in transverse sections, the commencement and gradual formation of the wood. It appeared evidently to spring from the tubes which, in my last Paper, (to which I must refer you,) I have called the returning vessels of the leaf-stalk; and to be deposited on the external sides of what I have there named the central vessels, and on the medulla. The latter substance appeared wholly inactive; and I could not discover any thing like the processes supposed to extend from it, in all cases, into the wood.

The organization of the young shoot is extremely similar to that of the leaf-stalk, previous to the formation of wood within it. The same vessels extend through both; and therefore it appeared extremely probable, that the wood in each would be generated in the same manner: and subsequent observation soon removed all grounds of doubt.

It is well known that, in the operation of budding, the bark of trees being taken off, readily unites itself to another of the same or of a kindred species. An examination of the manner in which this union takes place, promised some further information. In the last summer, therefore, I inserted a great number of buds, which I subsequently examined, in every progressive stage of their union with the stock. A line of confused organization marks the place where the inserted bud first comes into contact with the wood of the stock; between which line and the bark of the inserted bud, new wood regularly organized is generated. This wood possesses all the characteristics of that from which the bud was taken, without any apparent mixture whatever with the character of the stock in which it is inserted. The substance which is called the medullary process, is clearly seen to spring

from the bark, and to terminate at the line of its first union with the stock.

An examination of the manner in which wounds in trees become covered, (for, properly speaking, they never can be said to heal,) affords further proof, were it wanted, that the medullary processes, (as they are improperly named,) like every other part of the wood, are generated by the bark.

Whenever the surface of the alburnum is exposed but for a few hours to the air, though no portion of it be destroyed, vegetation on that surface for ever ceases. But new bark is gradually protruded from the sides of the wound, and by this new wood is generated. In this wood, the medullary processes are distinctly seen to take their origin from the bark, and to terminate on the lifeless surface of the old wood within the wound. These facts incontestibly prove, that the medullary processes, which in my former Paper I call the silver grain, do not diverge from the medulla, but that they are formed in lines converging from the bark to the medulla, and that they have no connection whatever with the latter substance. And surely nothing but the fascinating love of a favourite system, could have induced any naturalist to believe the hardest, the most solid, and most durable part of the wood, to be composed of the soft, cellular, and perishable substance of the medulla.

In my last Paper, I have supposed that the sap acquired the power to generate wood in the leaf; and I have subsequently found no reason to retract that opinion. But the experiment in which wood was generated in the leaf-stalk, apparently by the sap descended from the bark of the graft, induces me to believe, that the descending fluid undergoes some further changes in

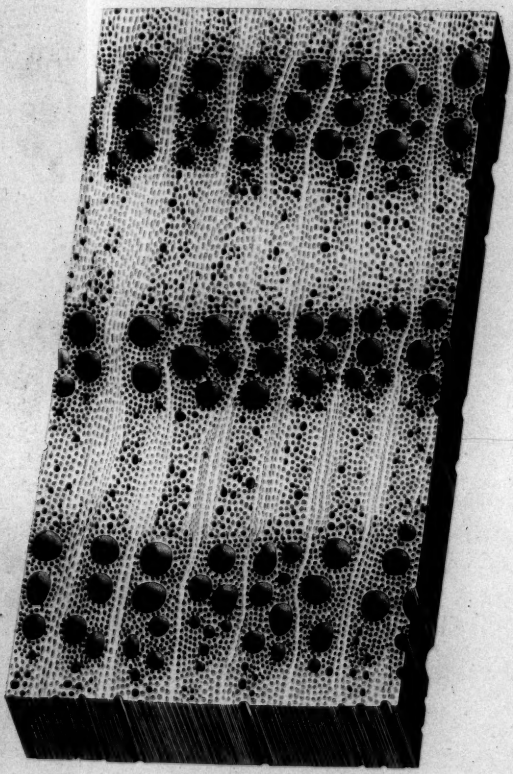
the bark, possibly by discharging some of its component parts through the pores described and figured by MALPIGHI.

I also suspected, since my former Paper was written, that the young bark, in common with the leaf, possessed a power, in proportion to the surface it exposes to the air and light, of preparing the sap to generate new wood; for I found that a very minute quantity of wood was deposited by the bark, where it had not any apparent connection with the leaves. Having made two incisions through the bark round annual shoots of the apple-tree, I entirely removed the bark between the incisions, and I repeated the same operation at a little distance below, leaving a small portion of bark unconnected with that above and beneath it. By this bark, a very minute quantity of wood, in many instances, appeared to be generated, at its lower extremity. The buds in the insulated bark were sometimes suffered to remain, and in other instances were taken away; but these, unless they vegetated, did not at all affect the result of the experiment. I could therefore account for the formation of wood, in this case, only by supposing the bark to possess in some degree, in common with the leaf, the power to produce the necessary changes in the descending sap; or that some matter originally derived from the leaves, was previously deposited in the bark: or that a portion of sap had passed the narrow space above, from which the bark had been removed, through the wood. Repeating the experiment, I left a much greater length of bark between the intersections; but no more wood than in the former instances was generated. I therefore concluded, that a small quantity of sap must have found its way through the wood, from the leaves above; and I found, that when the upper incisions were made at ten or twelve lines distance, instead of

one or two, and the bark between them, as in the former experiments, was removed, no wood was generated by the insulated bark.

I shall conclude my Paper with a few remarks on the formation of buds, in tuberous rooted plants, beneath the ground. They must, if my theory be well founded, be formed of matter which has descended from the leaves through the bark. I shall confine my observations to the potatoe. Having raised some plants of this kind in a situation well adapted to my purpose, I waited till the tubers were about half grown; and I then commenced my experiment by carefully intersecting, with a sharp knife, the runners which connect the tubers with the parent plant, and immersing each end of the runners, thus intersected, in a decoction of logwood. At the end of twenty-four hours, I examined the state of the experiment; and I found that the decoction had passed along the runners in each direction; but I could not discover that it had entered any of the vessels of the parent plant. This result I had anticipated; because I concluded, that the matter by which the growing tuber is fed, must descend from the leaves through the bark; and experience had long before taught me, that the bark would not absorb coloured infusions. I now endeavoured to trace the progress of the infusion in the opposite direction; and my success here much exceeded my hopes.

A section of the potatoe presents four distinct substances: the internal part, which, from the mode of its formation and subsequent office, I conceive to be allied to the alburnum of ligneous plants; the bark which surrounds this substance; the true skin of the plant; and the epidermis. Making transverse sections of the tubers which had been the subjects of the



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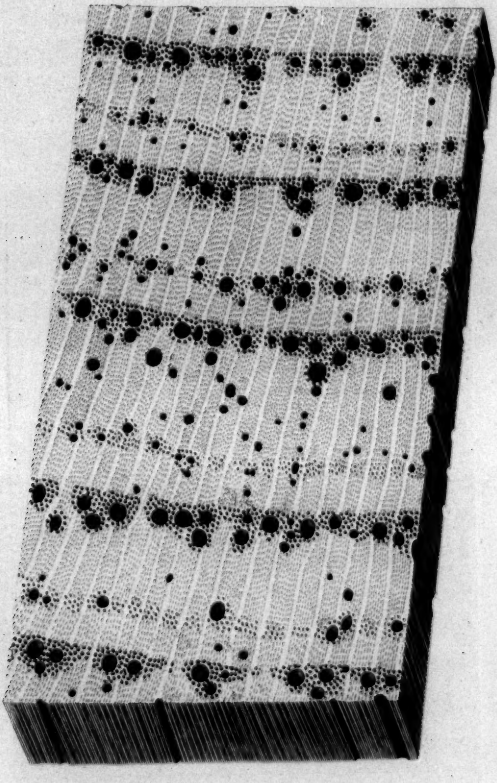

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experiments, I found that the coloured infusion had passed through an elaborate series of vessels between the cortical and alburnous substances, and that many minute ramifications of these vessels approached the external skin at the base of the buds, to which, as to every other part of the growing tuber, I conclude they convey nourishment.

Some other experiments were made on this plant, which appeared to me interesting; but my Paper has already a good deal exceeded its intended limits. I will therefore dismiss the subject; but intend to trouble you with another Memoir in the autumn, should this be honoured with the approbation of the Royal Society.

I am, &c.

T. A. KNIGHT.

Elton,
March 26, 1803.

XII. *Enquiries concerning the Nature of a metallic Substance lately sold in London, as a new Metal, under the Title of Palladium.* By Richard Chenevix, *Esq. F. R. S. and M. R. I. A.*

Read May 12, 1803.

On the 29th of April I learned, by a printed notice* sent to Mr. Knox, that a substance, which was announced as a new metal, was to be sold at Mr. Forster's, in Gerrard-street. The mode adopted to make known a discovery of so much importance, without the name of any creditable person except the vender, appeared to me unusual in science, and was not calculated to inspire confidence. It was therefore with a view to detect what I conceived to be an imposition, that I procured a specimen, and undertook some experiments to learn its properties and nature.

* "Palladium, or new silver, has these properties amongst others that shew it to "be a new noble metal.

"1. It dissolves in pure spirit of nitre, and makes a dark-red solution. 2. Green "vitriol throws it down in the state of a regulus from this solution, as it always does "gold from aqua regia. 3. If you evaporate the solution, you get a red calx that dis-"solves in spirit of salt or other acids. 4. It is thrown down by quicksilver, and by "all the metals but gold, platina, and silver. 5. Its specific gravity by hammering, "was only 11.3; but by flatting, as much as 11.8. 6. In a common fire, the face of "it tarnishes a little, and turns blue, but comes bright again, like other noble metals, "on being stronger heated. 7. The greatest heat of a blacksmith's fire would hardly "melt it; 8. But, if you touch it, while hot, with a small bit of sulphur, it runs as "easily as zinc.

"It is sold only by Mr. Forster, at No. 26, Gerrard-street, Soho, London; in "samples of five shillings, half a guinea, and one guinea each."

I had not proceeded very far, when I perceived that the effects produced by this substance, upon the various tests, were such as could not be referred, *in toto*, to any of the known metallic substances. I immediately returned to Mr. FORSTER, and became possessed of the whole quantity which had been left in his hands for sale. I could not obtain any information as to its natural state, or any trace that might lead to a probable conjecture.

The substance had been worked by art: it had been rolled out in flatting-mills; and was offered for sale in specimens consisting of thin laminæ. The largest of them were about three inches in length, and half an inch in breadth, weighing on the average 25 grs. and were sold for one guinea. The other laminæ were smaller, in proportion to the price.

Subjected to the same treatment as platina, to procure a polished surface, palladium assumed an appearance scarcely to be distinguished from that metal. The laminæ were not very elastic, but were very flexible, and could be bent several times in opposite directions without breaking. The specific gravity, I found to differ not a little from that which is stated in the printed notice, and to vary considerably in different specimens. Some pieces of the substance were as low as 10,972, while others gave 11,482.

The effects of GALVANIC electricity upon palladium, were the same as upon gold and silver. No oxidizement of the substance took place; but oxygen gas was emitted, during the whole time it formed a part of the GALVANIC circle in action.

A lamina of this substance being exposed to the blowpipe, the side removed from the immediate action of the flame became blue; but the temperature at which this colour was produced,

exceeded that at which steel begins to lose the tinge it had received at a lower heat.

I exposed palladium, in an open vessel, to a greater degree of heat than that which can melt gold. No oxidizement ensued; and, although the metallic slip was extremely thin, no appearance of fusion took place, even at the edges or corners. Upon increasing the fire considerably, I obtained a melted button; but I cannot estimate the degree at which the fusion was effected.

The button, by this treatment, had lost a little of its absolute weight; but its specific gravity had increased from 10,972 to 11,871. It was of a grayish-white. Its hardness was rather superior to that of wrought iron. By the file, it acquired the colour and brilliancy of platina. It was malleable to a great degree. Its fracture was fibrous, and in diverging striæ, which seemed to be composed of crystals; the surface of the button also, when seen through a lens, appeared to be crystallized.

Palladium very readily combines with sulphur. I exposed a certain quantity of it to a violent heat, without being able to melt it; and, at that elevated temperature, threw some sulphur upon it. It immediately entered into fusion, and remained in that state until the redness of the crucible was hardly visible in the daylight. The increase of weight in the button of the sulphuret, was such as could not indicate with exactness the proportion of sulphur combined with it; and I was so limited in the quantity of palladium I could obtain on any terms, that I thought it prudent to reserve as much as possible for the investigation of more important properties. Sulphuret of palladium is rather whiter than the substance itself, and is extremely brittle.

Palladium, melted in a charcoal crucible, and kept in fusion

for fifteen minutes, did not acquire any properties different from those which I have already mentioned, in speaking of the effect of heat upon that substance. Hence we may conclude, that there is not any action between charcoal and palladium.

I put equal parts of palladium and gold into a crucible, for the purpose of forming an alloy. The result, owing to an accident, did not weigh so much as the sum of the quantities employed; therefore, the proportions in this alloy were uncertain. Its colour was gray; its hardness about equal to that of wrought iron. It yielded to the hammer; but was less ductile than each metal separate, and broke by repeated percussions. Its fracture was coarse-grained, and bore marks of crystallization. Its specific gravity was 11,079.

Equal parts of platina and palladium, entered into fusion at a heat not much superior to that which was capable of fusing palladium alone. In colour and hardness, this alloy resembled the former; but it was rather less malleable. Its specific gravity, I found to be 15,141.

Palladium, alloyed with an equal weight of silver, gave a button of the same colour as the preceding alloys. This was harder than silver, but not so hard as wrought iron; and its polished surface was somewhat like platina, but whiter. Its specific gravity was 11, 290.

The alloy of equal parts of palladium and copper was a little more yellow than any of the preceding alloys, and broke more easily. It was harder than wrought iron; and, by the file, assumed rather a leaden colour. Specific gravity 10,392.

Lead increases the fusibility of palladium. An alloy of these metals, but in unknown proportions, was of a gray colour, and its fracture was fine-grained. It was superior to all the

former in hardness, but was extremely brittle. I found its specific gravity to be 12,000.

Equal parts of palladium and tin gave a grayish button, inferior in hardness to wrought iron, and extremely brittle. Its fracture was compact and fine-grained. Specific gravity 8,175.

With an equal weight of bismuth, palladium gave a button still more brittle, and nearly as hard as steel. Its colour was gray; but, when reduced to powder, it was much darker. Its specific gravity, I found to be 12,587.

Iron, when alloyed with palladium, tends much to diminish its specific gravity, and renders it brittle. Arsenic increases the fusibility of palladium, and renders it extremely brittle.

From these experiments, we may form the following Table, shewing the difference between the true and the calculated mean of specific gravity in the alloys of palladium.

	Metals	Proportion.	Specific gravity by calculation.*	Specific gravity by experiment.	Difference.
Palladium alloyed with	Gold -	uncertain.	uncertain.	11,079	uncertain.
	Platina -	equal parts.	17,241	15,141	— 2,100
	Silver -	equal parts.	10,996	11,290	+ ,294
	Copper -	equal parts.	10,176	10,392	+ ,216
	Lead -	equal parts.	uncertain.	12,000	uncertain.
	Tin -	equal parts.	9,340	8,175	— 1,165
	Bismuth	equal parts.	10,652	12,587	+ 1,935

* In the specific gravities of the different metals, I have followed the Table given in our best elementary work, Dr. THOMSON's System of Chemistry.

I exposed ten grains of palladium to the action of potash, in fusion, during half an hour. The substance lost its brilliancy, and diminished two grains and a half in weight: these were found in the potash.

The action of soda upon palladium, does not appear to be quite so violent.

Ammonia, allowed to remain for some days upon palladium, acquires a slight bluish tinge, and holds a small portion of oxide of palladium in solution. In all these cases, the action of the alkali is promoted by the contact of the atmospheric air, the oxygen of which combines with the metal, in favour of the affinity the oxide of palladium possesses towards the alkali.

Some of the pieces of palladium were more easily acted upon by the acids than others; and, in general, those of the greatest specific gravity were the least affected. Upon the whole, however, the following statement may be taken as the average of the habitudes of palladium with the acid solvents.

Sulphuric acid, boiled upon palladium, acquires a beautiful red colour, and dissolves a portion of the substance. The action of this acid is not very powerful, and, upon the whole, it cannot be looked upon as a good solvent for palladium.

Nitric acid acts with much greater violence upon palladium. It oxidizes the substance with somewhat more difficulty than it can oxidize silver; and, by dissolving the oxide, forms a very beautiful red solution. If the nitric acid be impregnated with nitrous gas, its action upon palladium is much more rapid.

Muriatic acid, by being boiled upon palladium for a considerable time, acts upon it, and becomes of a beautiful red.

But the true solvent of palladium is nitro-muriatic acid, which attacks it with great violence, and forms a beautiful red solution.

From all these acid solutions of palladium, a precipitate may be produced by the alkalis and earths. These precipitates are, for the most part, of a beautiful orange; are partly redissolved by some of the alkalis; and the supernatant liquor of the precipitate formed by ammonia is sometimes of a fine greenish-blue. Sulphate, nitrate, and muriate, of potash, or of ammonia, produce an orange precipitate in the salts of palladium, as in those of platina, when not in too dilute solution; and the precipitates from the nitrate of palladium are in general of a deeper orange. All the metals, except gold, platina, and silver, cause very copious precipitates in solutions of palladium. Recent muriate of tin produces a dark orange or brown precipitate in neutralised salts of palladium, and is an extremely delicate test. Green sulphate of iron precipitates palladium in the metallic state; and, if the experiment succeed, the precipitate is about equal in weight to the palladium employed. Prussiate of potash causes an olive-coloured precipitate; and water impregnated with sulphuretted hydrogen gas, a dark brown one. Fluoric, arsenic, phosphoric, oxalic, tartaric, citric, and some other acids, together with their salts, precipitate some of the solutions of palladium, and form various combinations with this substance.

Such are the principal characters I have found in palladium, examined as a simple metallic body. It does not appear that, in stating any of its properties, except its specific gravity, the printed notice has been guilty of misrepresentation.

From these experiments, it would be difficult to say of what metal, or of what combination of metals, palladium consists. We could not suppose gold or platina to be an ingredient in it, as it is in some measure acted upon by sulphuric and muriatic acids, and is wholly soluble in nitric acid. Silver is excluded, by

the effect of muriatic acid upon its solutions; as is lead, by that of the sulphuric. Tin, antimony, bismuth, or tellurium, would have left an insoluble residuum with nitric acid. No traces could be found of any of the acidifiable metals; and iron was looked for with particular care, but in vain. In a word, the precipitation by the metals, seems to exclude all those of easier oxidability than mercury; and this we should not suppose to be present, as copper is not in the least whitened, when used to precipitate palladium.

The striking similarity of many of the precipitates of palladium with those of platina, induced me to multiply the comparative experiments; and I constantly observed contradictory facts. The specific gravity, easy fusibility, combination with sulphur, precipitation by green sulphate of iron and by prussiate of potash, together with other effects, were such as I could not reconcile to the known characters of platina; unless I could suppose that a substance did exist, which could totally change its physical and chemical properties, or so disguise them as to render them proof against the evidence of chemical reagents.

The lightest of the metals is tellurium; yet, in order to produce an alloy of the specific gravity of palladium, (supposing for a moment the real density of the alloy equal to the calculated mean,) it would require two parts of tellurium and one of platina; and it is highly improbable, that so large a proportion of tellurium could exist in any mass, without being detected. We have been told of very extraordinary anomalies in chemical affinities, by Mr. BERTHOLLET; and Mr. HATCHETT has made us acquainted with some, not less extraordinary, in the properties of alloys. Yet I think we shall cease to wonder at what has been related by these chemists, when we learn that palladium is

not, as was shamefully announced, a new simple metal, but an alloy of platina; and that the substance which can thus mask the most characteristic properties of that metal, while it loses the greater number of its own, is mercury.

I confess it was not from an analysis of palladium that I was first led to this result; for I had convinced myself, by synthesis, of its nature, and had formed the substance, before I could devise any probable method of ascertaining its component parts.

In reflecting upon the various modifications which substances undergo when in union with each other, and on the variations produced in the laws of affinity by the intervention of new bodies, I was induced to try whether, by the affinity of platina with some metal easily reduced, it might not happen, that a reduction of both would take place by green sulphate of iron, although no such effect were produced upon each metal when separate. The most likely to succeed, as being most easily reduced, after gold, platina, and silver, was mercury. I poured some solution of green sulphate of iron into a salt of platina, and also into a salt of mercury; no precipitation took place. I united the two liquors; and a precipitate, exactly resembling that which is formed by green sulphate of iron in palladium, was instantly formed. I collected the precipitate, and exposed it to a strong heat; and, after repeated trials, obtained a metallic button, not to be distinguished from palladium.

It certainly is one of the most extraordinary facts respecting alloys, that two metals, by their union with each other, should so lose the characteristic properties of each individually, that neither of them can be immediately detected by the usual methods. Nothing but an affinity of the most powerful order could produce such effects. But, to place the metals under the

most favourable circumstances for that affinity to exert its influence, and to promote their union, is not the result of common methods. Among a great number which I have tried, many have failed, and none have been attended with uniform success. I have, however, formed palladium by the immediate union of platina and mercury; and, as whatever may place the apparent capriciousness of this combination in a conspicuous point of view is not devoid of interest, I shall describe the means by which I have attempted to produce it, whether they failed, or were attended with success.

SYNTHETICAL EXPERIMENTS.

Exper. 1. It was not till after repeated trials of the mode just mentioned, that I succeeded in forming palladium. In many instances, I obtained a button completely melted, of the specific gravity of 19, and sometimes more; not so easily fused by sulphur as palladium; not soluble in nitric acid; and the absolute weight of which exceeded that of the platina originally employed. But, although this substance was not platina, I could not say it was palladium. The most successful experiment by this method, was attended with the following circumstances. I dissolved one hundred grains of platina in nitro-muriatic acid, and then put in two hundred grains of red oxide of mercury, made by nitric acid; but this not being sufficient to saturate the excess of acid, I continued to add more, until it ceased to be dissolved. On the other hand, I prepared some green sulphate of iron, and poured it into a long-necked matrass. I then poured the mixed solution of platina and mercury into the solution of green sulphate of iron, and heated the whole upon a sand bath. In less than half an hour, a copious precipitate was formed; and the inside of the

matrass was lined with a thin metallic coat. The liquor was passed through a filtre, which I had weighed; and the precipitate, after digestion with muriatic acid, was well washed and dried. When I had collected as much of this as I could, there remained upon the filtre 12 grains; besides which, I had collected 264, in all 276. The supernatant liquor still contained a portion of mercury, and about eight grains of platina Therefore, the 276 were composed of 92 of platina, and 184 of mercury. From this it appears, that one hundred grains of platina, can determine the precipitation of near two hundred grains of mercury, by green sulphate of iron; and that, in this proportion, there is a reciprocity of saturation. The 264, collected from the filtre, were exposed to a low red heat, and were reduced to 144. The 12 of the filtre would have given about seven; therefore, the whole would have been 151. The substance was in the form of a fine powder, and had a metallic lustre. It was then put into a charcoal crucible, and fused into a button. This button weighed 128 grains, and, with the quantity left on the filtre, would have weighed 135. In this 135, there were 92 of platina; therefore, it was composed of about two parts of that metal and one of mercury. It was of the specific gravity of 11,2; was wholly soluble in nitric acid; was easily fused by sulphur; was precipitated by green sulphate of iron: in a word, it was not to be distinguished from palladium.

Exper. 2. As another mode of forming palladium in the humid way, I put metallic iron into a mixed solution of platina and mercury. Both metals were precipitated; and the precipitate was submitted to the same treatment as in the former case; but the success was not so complete. Iron can precipitate either platina or mercury separately; but green sulphate of iron can perform its function only in favour of the affinity of platina and

mercury. Their union is promoted by its action; and the effects are, in all probability, simultaneous. The combination of the metals takes place, if I may be allowed the expression, in their nascent metallic state, and in a fixed proportion of mutual saturation. The union of the two metals, therefore, is in the present experiment less intimate, and the button which results from fusing the precipitate, is of much greater density.

Exper. 3. The same process was repeated, only using zinc instead of iron, but the result was not more satisfactory.

Exper. 4. I poured some mercury into a solution of platina, and heated them together for some time. A precipitate took place; but, upon fusing it into a button, I did not find it to be palladium.

Exper. 5. I dissolved the same quantities of platina and mercury as in *Exper.* 1, in nitro-muriatic acid, and evaporated those solutions together. I then volatilized as much as I could of the mercury, at a red heat. At the end of the operation, I obtained precisely my original quantity of platina, reduced to the metallic state; but not one particle of the mercury remained along with it.

Exper. 6 and 7. The same quantities of platina and mercury, dissolved in nitro-muriatic acid, were precipitated by phosphate of ammonia; and the liquor was evaporated. The residuum, in a glassy state, was exposed to a violent heat in a charcoal crucible; and I obtained a melted button, which weighed more than the original quantity of platina, and was of the specific gravity of 14,5. On account of the easy fusibility of phosphuret of platina, I likewise tried to combine it directly with mercury, but could not succeed.

Exper. 8. I precipitated a mixed solution of platina and

mercury, by a current of sulphuretted hydrogen gas; and reduced the insoluble powder. After many attempts, in which I obtained buttons of the specific gravity of 14,3 and 14,5, I formed a piece weighing 11 grains, of the specific gravity of 11,5. This last was palladium; but I could not ascertain the excess of weight, as a part of the original precipitate had been lost.

Exper. 9. I mixed a solution of muriate of platina with prussiate of mercury, and obtained a slight precipitate. The liquor was evaporated, and the whole residuum exposed to a violent heat. This experiment did not succeed. It was not repeated so often as the others; but I have some reason to think it might be attended with success; for I obtained, in one instance, a few very minute grains, that were soluble in nitric acid.

Exper. 10. I heated some purified platina, in the form of a very fine powder, with ten times its weight of mercury, and rubbed them together for a long time. The result was, an amalgam of platina. This amalgam, exposed to a violent heat, lost all the mercury it had contained; and the original weight of the platina remained without increase.

Exper. 11. The best method of forming an amalgam of platina, is that prescribed by Count MUSSIN PUSHKIN. I dissolved a known quantity of platina in nitro-muriatic acid, precipitated by ammonia, and evaporated the liquor. The residuum was rubbed for a long time with a great quantity of mercury, and then exposed to a violent heat. Many operations failed; in some, I had a button of the specific gravity of 13,2. In one attempt, I succeeded completely: from 30 grs. of platina, treated as above, I obtained a button weighing 43,5, of the specific gravity of 11,736, which had all the properties of palladium.

Exper. 12. I fused together, in a charcoal crucible, 100 grs. of platina, 200 of cinnabar, 100 of lime, and 400 of calcined borax; and obtained a button, which weighed more than the platina, and was of the specific gravity of 15,7. It was not soluble in nitric acid; but combined with sulphur, at a red heat.

Exper. 13. In some experiments I had made, I found that the furnace in which I formed these alloys, was capable of melting platina, without the assistance of any flux except calcined borax. I therefore urged 100 grs. of platina, at a very strong heat; and, when I judged the fire to have attained its greatest intensity, I poured mercury upon the platina, through a long earthen tube that terminated in the crucible, and immediately withdrew the apparatus from the fire. No sensible union of the metals had taken place; nor had the platina increased in weight.

Exper. 14. I put 100 grains of platina into an earthen tube, and placed the tube horizontally in the above furnace. At one end of it was a retort, containing 2lbs. of mercury. When the tube was at its greatest heat, the mercury was made to boil; and the entire quantity passed over the surface of the platina, at that temperature. The experiment lasted one hour and a half; but the metals did not seem to have combined.

Exper. 15. Mr. PEPYS was so obliging as to try the effect of his very powerful GALVANIC battery, in forming palladium. A piece of platina-wire was plunged into a bason of mercury, and formed part of a GALVANIC circle. The wire was nearly in fusion; but no combination seemed to take place. The nature of this experiment did not allow of very accurate weighing; but the fused globules of platina did not appear to have acquired the properties that constitute palladium.

Such are the experiments by which I attempted to form

palladium. They were chiefly founded upon two principles; disposing affinity, and assimilation. In the one case, I endeavoured to present to the metals that compose it, a substance which, on account of its affinity for some menstruum necessary for their solution, and of their own tendency to combine in the proportions stated in *Exper.* 1, might cause them to unite in the form of an insoluble compound. In the other case, I hoped to assimilate the properties of each, and, by making them something more alike, to place them in the most favourable circumstances for uniting. *Exper.* 1 was founded on the former, and *Exper.* 8 on the latter of these principles.

In many instances, when I did not form palladium, I obtained a metallic button which was not platina; and, when I did so, it always weighed more than the original quantity of platina employed. In repeating *Experiments* 1, 2, 4, 6, 8, 11, and 12, I seldom failed of having such a substance. No effect of this kind took place in any experiment, when mercury was not used along with platina; and the other metals were merely accessaries, in promoting their union and precipitation. This is sufficiently proved, by the uniformity of the results in different processes, whether it was palladium or the substance I now mention which was formed. The chief property which distinguishes the latter substance from platina, is its density. It is not unusual to obtain it of a specific gravity so low as 13; very frequently 15 or 17. In the first experiments, I suspected this lightness to be owing to some air-bubbles; but repeated fusion, and comparative experiments upon platina, soon convinced me of the contrary. The augmentation of weight also, which the platina never fails of acquiring, proves that this metal has combined with some ponderable substance; and, in fact, the result of these operations

is, an alloy which is a mean betwixt platina in its pure state and what has been called palladium. It is, consequently, subject to infinite variation. The first effects which mercury produces upon platina are, to render it more fusible, and to diminish its specific gravity. The next new property conferred upon it is, the power of uniting with sulphur; and, lastly, it becomes soluble in nitric acid. It is not however till the specific gravity is below 12, or 12,5 at most, that it has acquired this property; and all these effects follow the direct order of the increase of weight observable in the platina.

It is not very difficult to combine a small quantity of mercury with platina: but, to resolve the problem completely, and to produce an alloy of these metals which shall be of so low a specific gravity as 11,8, and shall be soluble in nitric acid, is not so easily accomplished. From the repeated failures which I have experienced in these operations, I am much inclined to think that the author of palladium has some method of forming it, less subject to error than any I have mentioned. No doubt that perseverance would put us in possession of his secret; but, being prevented by want of leisure from pursuing these researches at present, I have confined myself to establishing the fact, and describing the processes which I have employed.

Having thus acquired a certainty that mercury is a constituent part of palladium, I made some further experiments upon it, with a view to its analysis; but they have not been attended with so much success. It might be expected, from the great number of methods which have failed to form palladium, that many might be found to decompose it when formed. But I have found the converse of such processes as did not succeed in producing palladium, to be ineffectual in destroying the combination.

ANALYTICAL EXPERIMENTS.

Exper. 1, 2, and 3. The converse of the synthetical experiments 1, 2, 3, was made, but without any satisfactory result.

Exper. 4. The converse of *Exper.* 4 was made without success. I put some mercury into a solution of palladium, and left them together for some time. The precipitate which was formed was palladium, just as it had been used for the operation.

Exper. 5. I exposed different pieces of palladium to a very violent heat for two hours. In some, a diminution of absolute weight, with an increase of specific gravity, took place; in others, neither of these effects was produced. The specimens which I had made were chiefly of the latter kind.

Exper. 6. Cupellation did not afford any satisfaction respecting the analysis of palladium; but the heat necessary for this purpose is so great, that I could not place great reliance upon this experiment. It is difficult to detach the button from the cupel with accuracy.

Exper. 7. I burned some palladium in oxygen gas. A white smoke arose during the combustion, and was deposited upon the sides of the glass jar that contained the gas. But this smoke was palladium, and not the mercury separated from it.

Exper. 8. A slip of palladium, which Mr. DAVY had the goodness to expose, in my presence, to the action of the strong GALVANIC batteries of the Royal Institution, burned with a very vivid light, and a white smoke; but no mercury was separated by this operation.

There is not any property of this compound which appears to me so wonderful, as that which is manifested by these experiments. It is a striking proof how unfounded was the opinion

of some philosophers, who supposed that the rapidity of combination was a measure of the force of affinity. We do not know of any affinity among chemical bodies which is more powerful than that of platina and mercury appears to be. The obstacles which must be overcome, in order to fix the latter metal, are a proof of this; yet the difficulty of forming this combination to its full extent is extreme. The difference which exists between the compound and its elements, when merely mixed, either in solution or otherwise, cannot be better exemplified than by comparing the result of the 5th synthetical experiment, with the difficulty of expelling mercury from the compound.

I must here observe, that all the analytical experiments, and many others, were made, by way of comparison, upon the palladium I had bought, as well as upon that which I had made. But, although I had myself combined the mercury with the platina, and consequently knew it to be in the compound that resulted, I could not succeed in separating it. Neither did the substance described in a former paragraph, as intermediate between platina and palladium, allow one particle of mercury to escape from it, by any process I have yet been able to devise.

The name of palladium conveys to our mind the idea of something absolute, and therefore incapable of gradation. But gradations in alloys are infinite; and the alloy of platina and mercury is susceptible of infinite variation. Palladium also brings to our recollection a contemptible fraud directed against science: the name, therefore, should not be admitted. I have called it an alloy; for it differs too much from the usual idea we have annexed to the word amalgam, but it accurately corresponds with our notions of the name I have adopted.

The facts which I have related in this Paper, appear at first

sight to have no similar examples in chemistry; and may not gain immediate assent from every person. The philosopher, indeed, will feel no humiliation in being forced to correct or to extend his knowledge; and will not altogether disbelieve a fact, because he can adduce no parallel instance, or because it is not in unison with his received opinions. Such conduct would be raising an insurmountable barrier against the progress of science: it would be setting up our own feelings in the place of nature; and attempting to measure what in itself is immeasurable, by the narrow scale of human comprehension.

But let us not confine our view of the facts and principles that have been mentioned, to this single instance. Let us trace them in a more extended circle; and see whether any thing may be found in nature that can apply to the present subject.

The first prejudice, for such I must call it, against the presence of platina in palladium is, the small density of the alloy. And no doubt it is extraordinary, that a metal the specific gravity of which is at least 22, (CHABANEAU says 24,) combined with another the specific gravity of which is nearly 14, should produce a mass of the specific gravity of 10,972; not much more than half of that which calculation would denote, and inferior to either of its elements. In Mr. HATCHETT's Paper upon the Alloys of Gold, to which I always refer with pleasure, we find some extraordinary instances of anomalies in specific gravity, both in excess and diminution upon the calculated mean. His experiments have not been doubted; nor can their accuracy be called in question. The principle of deviation in the true and the calculated mean is therefore admitted. Who then can say where this deviation shall end, or mark out limits to the operations of nature?

But a no less extraordinary instance of irregular density is daily before our eyes; yet it has not so much as attracted our attention. It is true that it is taken from among the gases. But, if we suppose that we have attained accuracy in experiments upon these subjects, I see no reason to refuse their evidence in this instance. The density of oxygen gas, to that of water, is as 1 to 740; and the density of hydrogen gas as 1 to 9792. The mean density of that proportion of oxygen and hydrogen gases which constitutes water, is to that of water as 1 to 2098; or, in other words, water is 2098 times heavier than the mean density of its elements in the gaseous state. But water is only 1200 times heavier than steam, or water in the state of vapour. Therefore, there is a variation in +, of 898, or nearly half, between the density of water and its elements, when both are in the aeriform state. This fact, however, regards bodies only as they remain in the same state, whether of solidity, liquidity, or fluidity. The anomaly is much greater, if we contemplate them as they pass from one of these states to the other. Yet we must not omit the consideration of such a change, in the instance of mercury alloyed with platina; for the former metal, before liquid, becomes solid as it enters into the new combination.

A stronger prejudice will perhaps exist against the fixation of so volatile a substance as mercury. It is certain that the labours of the alchemists have thrown some ridicule upon this subject, as a philosophical pursuit. Men of science have long since declined the research; and it is not probable that we are indebted to experiments undertaken in the true spirit of philosophy, for the present fixation of mercury. But, the same cause which induced us to look upon the project as chimerical, should dispose us to admit it when accomplished. Every chemist well knows,

that similar fixations of volatile substances are not uncommon. If an ore containing sulphur, or arsenic, or antimony, be gently roasted, a great part of those volatile bodies is driven off; but, if a fusing heat be suddenly applied, the mass unites in such a manner that a very small share of them escapes. Mr. HATCHETT has instanced an artificial combination of gold and arsenic, from which he could not expel the latter metal, by any degree of heat. Yet arsenic, though less fusible, is not much less volatile than mercury. I will also add a case still more in point; *viz.* the combination of arsenic and platina, which is not to be broken by a fusing heat.

An example of this fact, occurs again in water. The liquefaction or solidification of two gases to produce water, by a loss of caloric, never shocks our mind, because it is familiar to us. We cannot say what loss of caloric may be sustained by mercury, in order to unite with platina; or how far the presence of the latter may contribute to expel caloric from the former. We know too, that at any temperature, without the aid of a combustible body, to act as a reductive, we have not been able to disunite the last portions of oxygen, from the oxides of iron or of manganese. Yet, in the usual method of reducing a metallic oxide, the oxygen is surrounded by a much greater quantity of caloric than is necessary to convert it into gas. Every fixation of a volatile substance is analogous to the present question; and they whose minds have taken alarm from the novelty of the fact, may thus be familiarized with the necessity of admitting it.

But, it may be objected, in the instances of iron or manganese, oxygen is combined with a combustible body, and retained in it by a decided and powerful affinity. There is no reason to suppose

that such an affinity may not exist among metals. We have been forced to acknowledge it, in a few cases, among the earths; and, from the profound and sagacious researches of Mr. BERTHOLLET, we have learned many new facts, that promise us a rapid increase of knowledge. I shall beg leave to add a few examples, which are taken from that class of bodies to which the subject of the present Paper belongs, and show that the metals obey the general law of mutual attraction.

EXPERIMENTS TO PROVE AFFINITY AMONG THE METALS.

Exper. 1. I dissolved one hundred grains of silver in nitric acid, and precipitated by neutral muriate of platina. The precipitate, well washed and dried, was of a bright straw-colour, and weighed 147 grs. Reduced in a charcoal crucible, it yielded a button weighing 121 grs. and of the specific gravity of 11,6. The difference of weight, between the original hundred grains of silver and the 121, was owing to 21 grains of platina, which had been drawn down in precipitation along with the silver, by an affinity for that metal. This alloy is acted upon by nitric acid, and a great part of the platina is dissolved along with the silver; nor is it very easy to separate them by the common methods.

Exper. 2. I dissolved one hundred grains of silver in nitric acid, and added about 1200 of mercury. I poured the mixed solution into a solution of green sulphate of iron, and obtained a very copious precipitate. When washed and dried, it weighed 939, and was a perfect amalgam, in the due proportion of mutual saturation. Its specific gravity was 13,2; but no mercury remained with it after exposure to heat.

Exper. 3. I dissolved one hundred grains of gold in nitro-muriatic acid, and added to it about 1200 grains of mercury.

Green sulphate of iron, poured into this mixed solution, caused a precipitate weighing 874. It was in the form of a fine blue powder, not resembling an amalgam, though wholly metallic. Its specific gravity I could not ascertain; but all the mercury was expelled by heat.

The reagents which I used in the following experiments, were recent muriate of tin, and green sulphate of iron. To bring the examples of anomalous precipitations, in mixed solutions of the metals, more clearly into view, it will be necessary to state the action of these salts, upon a solution of each metal when separate.

By recent muriate of tin we have, with a solution of gold, the well known purple of CASSIUS. With platina, the colour of the liquor is much heightened. With mercury, there is a total reduction. With copper, a reduction from the black oxide at 20 *per cent.* of oxygen, to the yellow oxide at 11,5 *per cent.* of oxygen. With arsenic acid, a reduction to the state of white oxide. With silver, with lead, with antimony, no reduction. Green sulphate of iron reduces none of the metallic solutions, except those of gold and of silver.

When mixed solutions of the metals are exposed to the action of recent muriate of tin, or of green sulphate of iron, we have the following results.

Experiments 4, 5, 6, 7, and 8. Muriate of tin, poured into a mixed solution of gold and mercury, precipitates both metals together; and there are no traces of the purple. Mixed solutions of gold and antimony, also of gold and arsenic acid, are acted upon in the same manner. Mixed solutions of gold and copper, also of gold and lead, afford results similar to those of each metal when separate.

Experiments 9, 10, 11, 12, and 13. With a solution of platina and arsenic acid, muriate of tin gives no precipitate; but the colour of the liquor is more heightened than if the platina had been alone in solution. Platina and antimony give a precipitate by this reagent, after standing some time; but the effect is retarded by the excess of acid in the solution of antimony. Platina and copper, also platina and lead, are acted upon as the separate solutions of these metals. Platina and silver are precipitated together by green sulphate of iron.

Experiments 14, 15, 16. Mercury and copper, mercury and lead, also mercury and arsenic, are precipitated in the metallic state by recent muriate of tin.

From these experiments it is evident,

1st. That gold has an affinity for mercury, for antimony, and for arsenic.

2d. That platina has an affinity for silver, for mercury, and for antimony; and that it is influenced by the presence of arsenic.

3d. That silver has an affinity for mercury.

4th. That mercury has an affinity for copper, for lead, and for arsenic.

This series of experiments is not intended as a system of metallic affinities; but as a few facts stated to corroborate an assertion. I am well aware that many others might be noticed; but it is not my intention to enter further into this subject, in the present Paper. The general importance of the principle, and the extensive influence it is likely to have upon chemistry, demand that it should be treated by multiplied researches. The experiments that can elucidate it are of the most delicate nature, and require peculiar care; for they do not always succeed, unless performed under the most favourable circumstances.

When mixed solutions of three or more metals are exposed to the action of recent muriate of tin, or of green sulphate of iron, their action upon each other appears in a much more striking, as also in a much more complicated point of view.

EXPERIMENTS UPON PLATINA.

I shall now state some experiments which I have had occasion to make upon platina, during the foregoing researches. Very little is known concerning this metal, its oxides, or its salts; and, although I have not had occasion to extend the enquiries very far, yet my experiments may serve to establish a few points.

I dissolved a quantity of purified platina* in nitro-muriatic acid, and precipitated by lime. A great portion of platina remained in the liquor, although I had used an excess of the above earth. I redissolved the precipitate in nitric acid, and evaporated to dryness. The result was, a subnitrate of platina. I then exposed the mass, in a crucible, to a heat capable of expelling the acid altogether; and the oxide remained alone. When this was reddened, at a heat which certainly was not capable of melting silver, the oxide was reduced, and appeared with a metallic lustre. The weight of the various products, in the above experiments, was such as to give the following proportions in the oxide, and the subnitrate of platina.

Yellow oxide of platina is composed of,

Platina - - -	87
Oxygen - - - -	13
	100.

* By purified platina, I have always understood, in this Paper, platina reduced, at a gentle heat, from the salt obtained by pouring a concentrate solution of muriate of ammonia into a concentrate solution of platina.

Subnitrate of platina is composed of,

The above oxide of platina - -	89
Nitric acid and water - - -	11
	100.

But, in the reduction of this oxide of platina, it became of a green colour; and remained during some time in that state. Nitrate of platina sometimes becomes of a pale green at the edges, when evaporated to dryness; and ammonia assumes a green colour when it holds oxide of platina in solution, as we have seen more particularly with palladium. This, therefore, is a second oxide of platina. It contains but seven *per cent.* of oxygen.

I dissolved a known portion of platina in nitro-muriatic acid, and expelled the nitric acid, by pouring in a sufficient quantity of the muriatic; and then evaporated to dryness. By this experiment I learned, that the insoluble muriate of platina is composed of,

Yellow oxide of platina - -	70
Muriatic acid and water - -	30
	100.

I then expelled the muriatic acid by the sulphuric, and evaporated again to dryness. I found the insoluble sulphate of platina to be composed of,

Oxide of platina - - -	54,5
Acid and water - - - -	45,5
	100,0.

By much the most delicate test for platina is muriate of tin. A solution of the former, so pale as hardly to be distinguished from water, assumes a bright red by a single drop of the recent

muriatic solution of the latter metal. If mercury be present, the colour is much darker. Recent muriate of tin, poured into a solution of the muriate formed by the red oxide of mercury, converts it into the muriate formed by the less oxygenized acids; but, shortly after, the mercury is reduced to the metallic state. Hence it was, that the alloy of platina and mercury always gave a deeper coloured precipitate than platina, with muriate of tin.

Neither platina nor mercury are precipitated by prussic acid, or by the prussiates. But, if sulphate, nitrate, or muriate of platina be poured into prussiate of mercury, an orange-coloured precipitate is immediately formed; and, in some cases, a mixed solution of platina and mercury gives a similar precipitate by prussic acid alone.

Platina is one of the metals which are precipitated by sulphuretted hydrogen, without the necessity of a double affinity.

The affinities of platina differ much from what is generally stated in the tables. By the few acids I have had occasion to try, oxide of platina is attracted in the following order: sulphuric, oxalic, muriatic, phosphoric, fluoric, arsenic, tartaric, citric, benzoic, nitric, acetic, and boracic.

That sulphuric acid should attract the oxide of platina with greater force than the muriatic, is an unanswerable argument to an opinion which was long supported by many philosophers, and which is not yet altogether abandoned by them. Muriatic acid has been said to contribute to the solution of gold or platina, in nitro-muriatic acid, in the same manner as sulphuric acid is supposed to promote the decomposition of water, during the solution of iron by that acid diluted. The affinity of muriatic acid for the oxide of gold or of platina, has been looked upon

as the disposing cause that nitric acid is decomposed by those metals. But it is evident that some other action takes place; for, sulphuric acid, which has a stronger affinity for oxide of platina than muriatic acid, does not in the least promote the decomposition of nitric acid by gold, or by platina.

CONCLUSION.

The substance which has been treated of in this Paper, must convince us how dangerous it is to form a theory before we are provided with a sufficient number of facts, or to substitute the results of a few observations, for the general laws of nature. If a theory is sometimes useful, as a standard to which we may refer our knowledge, it is at other times prejudicial, by creating an attachment in our minds to preconceived ideas, which have been admitted without inquiring whether from truth or from convenience. We easily correct our judgment as to facts; and the evidence of experiment is equally convincing to all persons. But theories, not admitting of mathematical demonstration, and being but the interpretation of a series of facts, are the creatures of opinion, and are governed by the various impressions made upon every individual. Nature laughs at our speculations; and though from time to time we receive such warnings as should awaken us to a due sense of our limited knowledge, we are presented with an ample compensation, in the extension of our views, and a nearer approach to immutable truth.

The affinities of metals for each other are likely to be of the most extensive influence in chemistry. They will promote scepticism with regard to future discoveries, and throw some doubts upon our present knowledge. Palladium is certainly not less different from the elements that compose it, and from all other

metals, than any two can be from each other. Within the last fifteen or twenty years, several new metals and new earths have been made known to the world. The names that support these discoveries are respectable, and the experiments decisive. If we do not give our assent to them, no single proposition in chemistry can for a moment stand. But, whether all these are really simple substances, or compounds not yet resolved into their elements, is what the authors themselves cannot positively assert; nor would it in the least diminish the merit of their observations, if future experiments should prove them to have been mistaken, as to the simplicity of those substances. This remark should not be confined to later discoveries; it may as justly be applied to those earths and metals with which we have been long acquainted.

With regard to the metals, we have seen how little dependance is to be placed on specific gravities. A contrary anomaly to that which operates upon platina and mercury, may take place in others; and they may become as much heavier than the mean, as the former become lighter. In this state of union, they may for a long time appear homogeneous, even by the test of chemical reagents. One of the properties that renders metallic substances so precious is, their easy formation into such instruments as our necessities require. The fragile metals are but of secondary consequence; and, at most, serve to confer on those which are ductile, some quality which adapts them better to particular purposes. It often happens that, by being alloyed, two ductile metals become fragile; but we have no instance of the contrary effect in any high degree. It is therefore more to be supposed that we should look to simplification among the fragile metals; and, even at this early period, it may not be too

speculative, to consider the metallic bodies in an order which may bring together those which possess the greatest number of similar characters.

As an instance of this approximation, it may be observed, that nickel and cobalt strongly participate in the properties of copper and iron. The two former metals were long regarded as mixtures; and the doubts of the ancient chemists, who feared to pronounce as to their nature, may still be proved to have more foundation in truth than the assertion of the moderns, who have declared them to be simple. Acted upon by the same menstrua, forming insoluble compounds with the same acids, and soluble alike in other substances, they have but one or two marked properties that lead us to consider them as distinct metals. But palladium has at least five or six characters, as strong as those of any metal whatsoever, that distinguish it, not only from its elements, but also from all other metals.

Among the earths, this approximation is still more apparent. A leading character of these substances is, their tendency to enter into saline combinations, in which they receive new properties, and perform new functions. If we rank them according to this general tendency, we shall have the following order: barytes and strontia; lime and magnesia; glucine and alumina; zircon and silica. And, if we consider them two by two in this order, which is a natural one, we shall bring together precisely those which differ by the smallest number of chemical characters.

This investigation might be pursued still further; but we must wait the result of experiments: a wide field is open for research. In the dark ages of chemistry, the object was, to rival nature; and the substance which the adepts of those days were

busied to create, was universally allowed to be simple. In a more enlightened period, we have extended our enquiries, and multiplied the number of the elements. The last task will be to simplify; and, by a closer observation of nature, to learn from what a small store of primitive materials, all that we behold and wonder at was created.

XIII. *An Account of the sinking of the Dutch Frigate* Ambuscade, *of 32 Guns, near the Great Nore; with the Mode used in recovering her. By Mr.* Joseph Whidbey, *Master Attendant in Sheerness Dock Yard. Communicated by the Right Hon. Sir* Joseph Banks, *Bart. K. B. P. R. S.*

Read April 28, 1803.

At eight o'clock in the morning of the 9th day of July, 1801, the Dutch frigate Ambuscade left the moorings in Sheerness harbour, her fore-sail, top-sails, and top-gallant-sails being set, with the wind aft, blowing strong. In about thirty minutes, she went down by the head, near the Great Nore; not giving the crew time to take in the sails, nor the pilot or officers more than four minutes notice, before she sunk; by which unfortunate event, twenty-two of the crew were drowned.

This extraordinary accident was owing to the hawse-holes being extremely large and low, the hawse-plugs not being in, and the holes being pressed under water by a crowd of sail on the ship, through which a sufficient body of water got in, unperceived, to carry her to the bottom.

The instant she sunk, she rolled over to windward across the tide, and lay on her beam ends; so that, at low water, the muzzles of the main deck guns were a little out of the water, and pointed to the zenith, with 32 feet of water round her.

The first point I had to gain, was to get her upright. Before

I could accomplish it, I was obliged to cut away her fore-mast, and main-top-mast; which had no effect, until the mizen-mast was also cut away; she then instantly lifted her side, so that, at low water, the lee railing on the quarter deck was visible.

By proceeding in this manner, the first part of my object was obtained, with a secured main-mast, and all its rigging, to enable me, should I be fortunate enough to weigh the ship, to lighten her by it with the greatest possible expedition.

The ship being in the forementioned state, gave me an opportunity, the next low water, to get out her quarter, forecastle, and some of her main-deck guns, with a variety of other articles.

I next proceeded to sling her; which was done with two nineteen-inch cables, divided into eight equal parts. The larboard side of the ship being so much higher than the starboard, enabled me to clench each of the ends round two of the ports, excepting one that was clenched round the main-mast; and, with great difficulty, by long rods and diving, I got small lines rove through four of the ports on the starboard side, by which means, I got four of the cables through those ports across her deck, which were clenched to the main-mast and larboard side, having four ends on each side completely fast, at equal distances from each other. I brought the Broederscarp, of 1063 tons burthen, out of the harbour, which received the four ends on the starboard side; also four lighters, of 100 tons each, which took in the other four ends, on the larboard side, over their bows. All the eight ends were at low water hove down with great power, by a purchase lashed distinctly on each of them. I then laid down two 13-inch cables, spliced together, with an anchor of

24 *cwt.* in a direction with the ship's keel. On the end of the cable next the frigate a block was lashed, through which was rove a 9-inch hawser, one end of which was made fast to the ship; the other end was brought to a capstan on board the Broederscarp, and hove on it as much as it would bear, with an intention to relieve the frigate from the powerful effect of cohesion. This had so far the desired effect that, at about half flood, I perceived the ship to draw an end, and swing to the tide; and all the slings were considerably relieved. At high water, she was completely out of her bed. At the next low water, I hove all the purchases down again. At half flood she floated; and the whole group drove together into the harbour, a distance of three miles, and grounded the frigate on the west side of it. It took me two tides more to lift her on the shore, sufficiently high to pump her out; which was then done with ease, and the ship completely recovered, without the smallest damage whatever, either to her bottom or her sides.

I do not apprehend there is any thing new in the mode I adopted in weighing the Ambuscade, excepting the idea of removing the effect of cohesion, by the process before described; and I have every reason to think, that if that principle had been acted on, in the attempt made to weigh the Royal George, it would have succeeded.

I am, &c.

EXPLANATION OF THE FIGURES.

Plate V. Represents the Ambuscade Dutch frigate, as weighed from the east end of the Middle Sand, near the Great Nore, on the 17th of July, 1801.

Fig. 1. Broederscarp Dutch hulk.

Fig. 2. Chain lighter.

Fig. 3. Goodwill, Medway, and Sheerness, sailing lighters.

Fig. 4. The frigate Ambuscade.

Fig. 5. Section of ditto, showing her position, with the height of water, as marked by the dotted line, at low water; the tide rising sixteen feet.

Fig. 6. Cohesion cable, of 13 inches; 900 fathoms in length.

Fig. 7. Anchor of 24 *cwt.*

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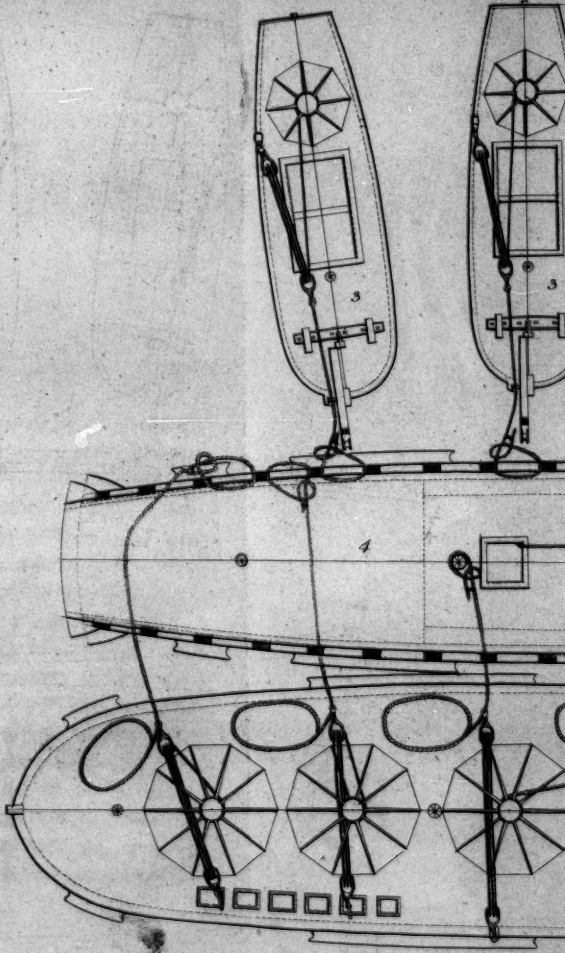
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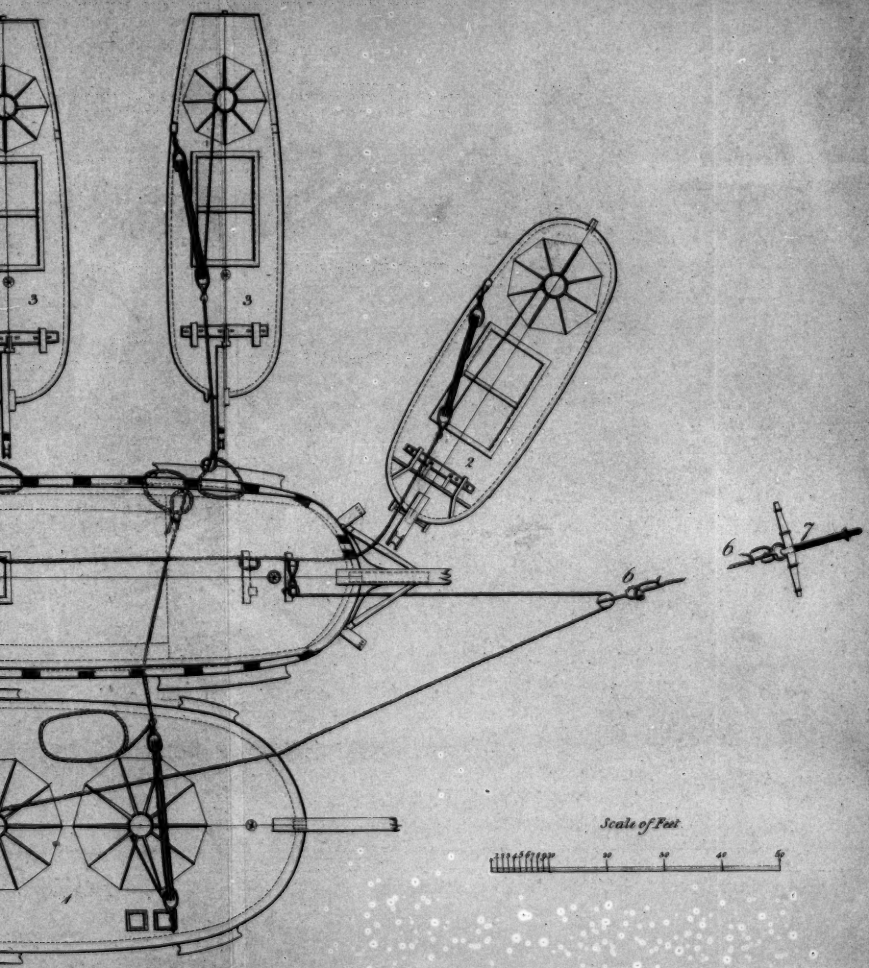


Basire sculp.

FRANKLIN INSTITUTE

XIV. *Observations on a new Species of hard Carbonate of Lime; also on a new Species of Oxide of Iron.* By the Count de Bournon, *F. R. S. and L. S.*

Read May 26, 1803.

CARBONATE OF LIME.

A PARTICULAR investigation which I undertook to make, of the immense variety of forms presented to us by the carbonate of lime, (many of which have never yet been described,) having led me to observe more accurately some specimens I had before examined, my attention was forcibly attracted by a group of hexaedral pyramidal crystals, which are in Mr. GREVILLE's noble collection. As the exterior appearance of these crystals was different from that which is peculiar to carbonate of lime, I was desirous to ascertain their nature, and therefore endeavoured to bring them, by splitting, into the primitive rhomboidal form of this substance; but, upon making the attempt, I perceived, to my great astonishment, not only that I was not able to obtain any fracture that could possibly belong to the planes of the primitive rhomboid, but also, that the substance strongly resisted every attempt I made to procure a fracture in any other direction. In fact, every fracture I could obtain was irregular, and possessed more or less of that vitreous appearance which is peculiar to the greater number of hard stones. So remarkable was the hardness of this substance, that, although the points of the crystals were very thin, and consequently might

be supposed very brittle, yet they resisted my efforts to break them, in a very remarkable manner.

The resistance above spoken of appearing to me analogous to that of hard stones, I resolved to examine, with the most scrupulous attention, every thing relating to the peculiar characters of this substance.

Its hardness is very superior to that of common carbonate of lime, being such as to scratch very easily the fluate of lime; and, when rubbed with force upon glass, it takes off the polish of its surface, and sometimes leaves scratches upon it.

Its specific gravity, I found to be 2912.

This substance, of which I have since had an opportunity of observing a great number of specimens, I have always found to be without colour; and its crystals are very often perfectly transparent.

When powdered, and thrown upon a piece of iron heated nearly to redness, in a place that is perfectly dark, it occasions a very weak phosphorescent white light; this light is only sufficient to mark the place where the powder is thrown.

Its lustre is much greater than that of common carbonate of lime.

When put into nitric acid, a violent effervescence is produced; and it is very quickly dissolved, without leaving the smallest residuum.

Although this substance strongly resists any effort made to divide it by splitting, yet it shows a tendency to admit of being divided more easily in two directions, which would produce a rhomboidal tetraedral prism. I succeeded indeed, at last, though with great difficulty, and after many fruitless attempts, in procuring from it a perfect rhomboidal tetraedral prism, the angles

of which measured 128° and 52. (See Plate VI. Fig. 1.) I found it, however, impossible to obtain any smooth and even fractures on the terminal faces of this prism.

In some crystals, which were situated at the base of those which constituted the largest of the groups I examined, I observed perfectly-formed hexaedral prisms, which appeared to me to have been occasioned by the two angles of 52° (belonging to the rhomboidal tetraedral prism of 128° and 52°, which I have just described,) having been replaced; consequently, there were now two edges of 128°, and four others of 116°. See Fig. 2.

The principal crystals which form the above group, although they are about three inches in length, do not show themselves distinctly, except at their upper extremity, being joined together, and entangled with each other, throughout the rest of their length. The upper extremity just mentioned, is a very sharp hexaedral pyramid, as in Fig. 3. The solid angle of its summit, taken upon two of the opposite sides, is of 15°; and the sides of the pyramids, meeting together, form two angles of 128° each, and four others of 116°, as we have already seen to be the case with respect to the sides of the hexaedral prism; consequently, the base of this pyramid is an irregular hexagon.

Although the summit of this pyramid is sometimes formed in the manner above described, by the meeting of all its planes at the same point, (as is seen in Fig. 3,) yet it more frequently happens that the summit terminates in a ridge; the pyramid is then of a cuneiform shape, on account of the extension (which is sometimes very considerable) of two of its opposite sides, at the expense of the others, as in Fig. 4. Very frequently, indeed, the abovementioned extension is such as to cause the pyramids to be extremely thin; they then appear in the form of a very,

acute isosceles triangle, the summit of which is truncated, and the sides of which are slightly bevelled. The bevel, however, is often so inconsiderable as to be scarcely perceptible. See Fig. 5.

Each of the two sides which, in those pyramids, acquire the abovementioned extension of surface, at the expense of the two others, has constantly appeared to me to belong to one of the sides which forms the angle of 128°, but taken in an opposite direction, as is represented in Fig. 6, which is supposed to be the base of one of them. This base is perfectly similar, in the measure of its angles, to that of the hexaedral prism of Fig. 2; nevertheless, this hexaedral prism sometimes appears also to have the two planes, which have replaced the edges of 52°, more extended than the four others.

In those crystals which are the most detached from each other, and exhibit a larger portion of their extent, it may be distinctly perceived, that the above pyramid is situated upon a hexaedral prism, of the same dimensions as the base of the pyramid; (see Fig. 7;) but, as the angle formed by the junction of the sides of the prism with those of the pyramid is extremely obtuse, (its measure being 172° 30′,) the exact point of union of the prism with the pyramid cannot easily be distinguished.

The summit of the pyramid is sometimes replaced by two trapezoidal planes, situated, when the pyramid is of a cuneiform shape, on the broadest sides. These planes meet together, at the summit, in a ridge of 110°, and form, with the sides of the pyramid, on which they incline, an angle of 152° 30′. See Fig. 8.

At other times, this summit is replaced by two planes situated differently from the above, being placed on one of the edges contiguous to each of the two broad sides of the pyramid, and in opposition to each other. These planes, which are irregular

pentagons, meet together at the summit, in a ridge which is perpendicular to the axis, and form, with the edges of the pyramids, on which they incline, an angle of 140°, as in Fig. 9. These planes are sometimes very distinctly striated, the striæ being directed towards the summit; but, by following these striæ over the whole surface of the crystal, it evidently appears, that they are occasioned by the aggregation of a greater or smaller number of very thin crystals, which are united by the broadest sides of their pyramids.

Many of the crystals exhibit this variety combined with that represented in Fig. 8, as is seen in Fig. 10. The summit of the crystal is then terminated by a small tetraedral pyramid.

It frequently happens, that there exists only one of the planes of the diedral summit, represented in Fig. 9. It nevertheless intercepts the summit of the pyramid, which then becomes terminated by a hexagonal plane, inclined upon one of the edges contiguous to one of the broad sides, in such a way as to form with it an angle of 140°. (See Fig. 11.) These crystals are very often so considerably flattened, as to have nearly the appearance of very sharp isosceles triangular laminæ, which have their summits truncated, in such a manner as to form with one of the broad sides an angle of 140°, as in Fig. 12. I have seen crystals of this variety, the thickness of which scarcely exceeded that of a sheet of paper; yet, notwithstanding their thinness, I found that they might easily be handled, without danger of being broken.

Lastly, the summit of the hexaedral pyramid is sometimes terminated by a plane that is perpendicular to its axis. But I have never seen this last variety, except in combination with that represented in Fig. 9. This combination is shown in Fig. 13.

The above are all the forms I have been able to discover, in the species of carbonate of lime here described.

This substance does not appear to be very scarce. Among the crystallized carbonates of lime preserved in Mr. GREVILLE's collection, I have met with about a dozen specimens of it, most of which came either from Carinthia, or from Transylvania, or from Scotland. The beautiful and delicately white stalactitical substance, hitherto known by the name of *flos ferri*, generally belongs to the substance here described, particularly certain pieces of it, which have their ramifications covered with small brilliant asperities, giving them the appearance of fine satin. These little asperities, all of which are inclined, in the same direction, to the axes of the various ramifications, are in fact so many very perfect but minute crystals, which most commonly belong to the forementioned flat pyramidal varieties.

Among the specimens of this kind of carbonate of lime which came from Carinthia, there exist some, in which the sharp pyramids are very small, and appear as if planted almost perpendicularly in the matrix. These specimens may, from the above circumstance, be more easily confounded with the common carbonate of lime in small needle-like crystals; there is, however, the following difference between them, namely, that in the common carbonate of lime, we cannot touch these little crystals, though ever so lightly, without breaking them; whereas, in the substance here described, the crystals are capable of resisting a tolerably strong compression of the fingers, and, if the pressure be increased, they very frequently, instead of breaking off, actually penetrate into the skin. The lustre of the latter substance is also much more lively than that of the former.

Another circumstance which might prevent our recognizing, at the first view, the crystals of this substance, when placed among those of common carbonates of lime, is, that the crystals of the latter substance are sometimes found in the form of a hexaedral pyramid, nearly as acute as that of the crystals above described; but, in that case, they break with the greatest facility, and the fractures are always smooth, and in the direction of the planes of the primitive rhomboid; a circumstance that is never observed in the crystals of the hard carbonate.

The matrix of this substance, in most of the specimens I have seen, is a brown oxide of iron, mixed with a portion of argill, and also with a considerable number of calcareous particles. In some of these may be observed the primitive rhomboid of the common carbonate of lime, grouped upon the crystals of the substance here treated of.

It may perhaps be questioned, whether the hard carbonate of lime I am now describing, (the mineralogical characters of which seem so much at variance with the chemical ones,) ought not to be referred to that kind which mineralogists have been already obliged to separate from the others, under the name of Arragonite, or whether it ought to be considered as different from the latter substance, and forming an additional new species, among the combinations of the carbonic acid with lime. It appears to me very difficult to determine the above question. The primitive crystal which I obtained from it, is not sufficiently perfect to serve as an accurate criterion; for, as we have seen, that crystal, which is a rhomboidal tetraedral prism, cannot be divided according to its basis, that is, in one of its three natural directions; and this is exactly similar to what happens with respect to the primitive crystal obtained from the Arragonite. I confess, however, that if I were obliged to adopt an opinion, I should

be inclined to consider these two substances as distinct from each other.

I shall now take a short view of the analogy, and of the difference, existing in the characters of the two substances just mentioned.

Their specific gravity is nearly the same. The Abbé HAUY states that of the Arragonite at 2946. I found that of the hard carbonate of lime to be 2912.

The hardness of the latter is rather greater than that of the former: it scratches the Arragonite, but is not scratched by it.

The Arragonite is seldom found without a tinge, more or less considerable, of purple; but I have never observed any appearance of colour in the hard carbonate of lime.

The Arragonite, when thrown upon a heated iron, emits a very brilliant phosphorescent light, of a yellowish-orange colour. The other substance, when treated in the same manner, produces only a white phosphorescent light, scarcely perceptible.

From the Arragonite is obtained, by splitting, a rhomboidal tetraedral prism, of 116° and 64°; and, from the hard carbonate of lime, one of 128° and 52°.

The last-mentioned substance, in its secondary forms, passes into a hexaedral prism, which has two edges of 128°, and four others of 116°. Whereas, the Arragonite becomes a hexaedral prism only in consequence of the union of several of its rhomboidal prisms; and as, in that state, three of the edges of the prism are formed by the union of the edges of 64°, belonging to the tetraedral prism, it has three angles of 116°, and three others of 128°. This gives 732°, for the whole measure of the angles of the prism; which measure is too great by 12°; and is the cause that, in the formation of the prism, the rhomboids of which it is composed, are obliged sometimes to penetrate

each other; at other times, to form a re-entering angle, at the angles of 128°.

In another secondary form assumed by the Arragonite, there is a diedral summit with isosceles triangular planes, which are inclined upon the edges of 64°, belonging to the tetraedral prism, and meet together in a ridge of 110°. I have not perceived any trace of this form, in the kind of carbonate of lime treated of in this Paper; nor have I perceived the smallest trace of the pyramidal forms of the last-mentioned substance, among the crystals of the Arragonite.

Neither the hard carbonate of lime nor the Arragonite exhibit, by their chemical analysis, any signs of the cause that occasions them to differ from the common carbonate of lime. The Arragonite has been very carefully analysed by MM. KLAPROTH, VAUQUELIN, and THENARD; but their analyses did not show that it differed, in the smallest degree, from the common carbonate of lime. I desired Mr. CHENEVIX to be so good as to analyse the hard carbonate of lime; but his result was not more satisfactory. The cause of its difference from common carbonate of lime remains still undiscovered; yet there certainly exists a considerable difference between the two substances, and one which even the chemist is compelled to admit, when he takes the hard carbonate of lime into his hands, and which becomes still more evident to him, the moment he begins to reduce it into powder. It is however very clear, that the said difference arises from a cause which has hitherto eluded the investigations of chemistry. It may perhaps be supposed, that it is owing to the constituent particles of the substance being more closely connected; and this indeed might be sufficient to occasion a greater degree of specific gravity, and of hardness. But, in the first place, it may be asked what can produce this more intimate connection,

of which we find no other example in the immense quantity of crystallized carbonate of lime that has been hitherto examined, however perfect the form of the crystals, or however great their degree of transparency. In the second place, why should the above-mentioned cause change the character of the crystalline forms of carbonate of lime, when we see no instance of such a change in the crystalline forms of other substances, even when they show, by an increase in their hardness, in their specific gravity, and in their transparency, that a closer connection between their constituent particles has actually taken place.

It appears therefore impossible, in the present state of our knowledge, to determine the cause of the very great difference that exists between the common carbonate of lime and the hard kind here treated of; yet it is equally impossible not to be sensible, that the said difference is of such a nature as absolutely prevents us from considering them as of the same species. Whether it is right to join the hard carbonate of lime with the Arragonite, is a question I have already in some measure discussed, but respecting which, until I have had further opportunities of investigating the matter, I shall not venture to give a decided opinion.*

* I have lately received, from my worthy friend M. GILLET DE L'AUMONT, some imperfectly formed and colourless crystals of hard carbonate of lime, which, he says, were found inclosed in lava, near Vertzou, in the environs of Puy de Dome, in Auvergne, and which were considered as a kind of Arragonite. These crystals appear to me very similar to the hard carbonate of lime herein described; and M. GILLET informs me, that the above is not the only part of Auvergne in which these crystals are found in old lava. I remember perfectly well, that when I was examining the volcanic products of that province, on the spot, and also those of Velay, of Vivarais, and of Forez, I observed, in many of the lavas of the extinct volcanos of those provinces, groups of thin diverging crystals of carbonate of lime, which appeared to me much harder than crystals of common carbonate of lime in similar circumstances, so that I found it very easy to preserve them entire. I think it very probable, that the *Arragonite cylindroide* of the Abbé HAUY ought to be referred to this substance.

CUBIC OXIDE OF IRON.

Amongst the various examples which mineralogy, when studied with attention, constantly offers to us, of several different species being included in the combination of the same modifying substance with the same base, iron may be considered as affording one of the most striking. This metal, in its combinations with oxygen, varies considerably; insomuch that it presents us with several different species, according as the proportion of oxygen in the combination is increased. Thus, by the first degree of oxidation in which this metal offers itself to our notice, is formed the very attractable oxide of iron, which crystallizes in regular octaedrons. By the second degree of oxidation, in which there is a greater proportion of oxygen, a different oxide is produced, which is much less attractable than the former, and crystallizes in the form of a slightly acute rhomboid. Lastly, in the third degree of oxidation, in consequence of a still greater proportion of oxygen, the attractable property no longer exists; the power of crystallizing entirely ceases; and we have the ores called hæmatites, and the other earthy oxides, for instance, the brown, the red, the yellow, and the black, (the appearance of which latter very much resembles that of a bitumen,) between which there certainly exists some real chemical difference, that will probably hereafter be discovered.

The distinction of species here spoken of will perhaps appear extraordinary, to those persons who are accustomed to consider the combination of oxygen with iron as forming of itself a species in the genus, (which genus is determined by the nature of the metal, namely, iron,) because it may appear to them like dividing into various species, that which merely constitutes a single one. But I must observe, that in mineralogy it is not

merely the chemical combination of a particular acid with a particular basis which forms the species, but the mode in which that acid is combined with the basis. Perhaps, in many cases, the formation of the species may depend upon the introduction of a third principle, which, either from its mode of combination or from its nature, has hitherto eluded the investigations of chemistry. Thus, in the analysis of two plants, or of two animals, of totally different species, chemistry, in most cases, is not able to discover any thing but the same ingredients combined with each other. In these instances, therefore, it is evident that the mode of combination, and not the combination itself, is what determines the species.

The science of mineralogy is indebted to the Abbé HAUY, for having ascertained the primitive form of the slightly attractable oxide of iron, formerly known by the name of specular iron ore, to which he has given the name of *fer oligiste*. That form was supposed to be derived from the cube; but the Abbé HAUY, directed thereto by the secondary crystals, has shown that it belongs to a rhomboid of 87° and 93°. Nevertheless, the cube must not be excluded from among the forms belonging to the oxides of iron. On the contrary, it constitutes a particular species, which has hitherto been entirely overlooked by mineralogists.

Between the slightly attractable oxide of iron, (or specular iron ore,) and that kind which no longer crystallizes, except in a very indeterminate form, nature has placed another species, the surface of which is of a gray colour, and has a specular appearance, pretty much like the iron ore from the island of Elba. This kind is not at all acted upon by the magnet; and seems to be in the last degree of oxidation in which iron retains the property of crystallizing in a regular form.

Its form is a perfect cube, the edges or solid angles of which are sometimes replaced by small planes.

Its fracture is conchoidal: it has a smooth grain, with a small degree of lustre; and, although it is impossible to make a regular fracture in any particular direction, yet the fracture shows that the crystalline laminæ, or collection of molecules, are situated on the surface of the cube.

Its hardness is rather inferior to that of the slightly attractable oxide of iron.

Its specific gravity is very low; I found it to be only 3961.

Its powder is more red than that of the slightly attractable oxide of iron, but has not the yellow cast observed in the powder of the hæmatite.

To this species ought to be referred the *eisen-glimmer* of the Germans, when it is not attractable: when, on the contrary, it is attractable, it belongs to the slightly attractable oxide of iron. In the first case, this *eisen-glimmer* is in small laminæ, which are very brilliant, but of an indeterminate form; and it frequently is found accompanying the hæmatites, and having the abovementioned appearance. If, in the formation of the hæmatites, some particles of the oxide of iron of which they are composed happen to contain a rather smaller proportion of oxygen, they naturally become the cubic oxide of iron here treated of. Indeed, some hæmatites, although they are crystallized in a very indeterminate manner, and are really of a species different from the cubic oxide of iron, show, by the colour and brilliancy of their surface, a tendency to approach towards it.

When the octaedral very attractable oxide of iron (the *fer oxidulé* of the Abbé Hauy) is in irregular and confused masses, the cubic oxide of iron here described is sometimes found mixed with it; and, in that case, it renders the ore less sensible to the

influence of the magnet, in proportion to the quantity of it contained in the mixture. Its presence may be easily detected, when the ore is pounded, by the appearance of a red powder, which shows itself in the middle of the black powder of the aforesaid ore.

Among the specimens of iron ore from Gellivare, in Swedish Lapland, which were brought here by Mr. SWEDENSTIERNA, a very intelligent Swedish mineralogist, there were some, in which this cubic oxide of iron was so pure and unmixed, that they were not at all, or at least in a very slight degree, acted upon by the magnet; but, that they really belonged to the species here treated of, might be plainly perceived, by pretty strongly marked striæ upon the surface, which crossed each other at right angles, and were sometimes even seen within the substance. In other specimens, the cubic oxide of iron was mixed, in greater or less proportion, with the octaedral kind; and this latter became, in that case, less attractable, in proportion as the former species was more abundantly mixed with it. Those who have been accustomed to examine this species, and are in the habit of using a lens, (without which many interesting objects in mineralogy escape our observation,) may become capable of distinguishing it in the ore; and this faculty may perhaps hereafter be of great importance, provided it should be found that the quality of the iron obtained from the ore, is affected by the abovementioned mixture. If we scratch with a knife such specimens as contain both the abovementioned species, we may, indeed, by the appearance of a red powder, discover the particles of the cubic oxide, (which particles, if separated, would not be attractable,) and we may thereby, in some measure, estimate the proportion of the above oxide in the ore.

Fig. 1.

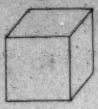


Fig. 2.

Fig. 3.

Fig. 4.

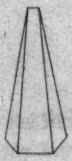


Fig. 5.

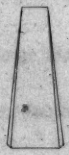


Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

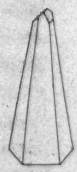


Fig. 10.

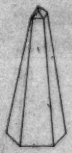


Fig. 11.

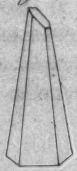
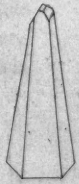


Fig. 12.

Fig. 13.



XV. *Account of the Changes that have happened, during the last Twenty-five Years, in the relative Situation of Double-stars; with an Investigation of the Cause to which they are owing.* By William Herschel, *LL. D. F. R. S.*

Read June 9, 1803.

In the Remarks on the Construction of the Heavens, contained in my last Paper on this subject,* I have divided the various objects which astronomy has hitherto brought to our view, into twelve classes. The first comprehends insulated stars.

As the solar system presents us with all the particulars that may be known, respecting the arrangement of the various subordinate celestial bodies that are under the influence of stars which I have called insulated, such as planets and satellites, asteroids and comets, I shall here say but little on that subject. It will, however, not be amiss to remark, that the late addition of two new celestial bodies, has undoubtedly enlarged our knowledge of the construction of the system of insulated stars. Whatever may be the nature of these two new bodies, we know that they move in regular elliptical orbits round the sun. It is not in the least material whether we call them asteroids, as I have proposed; or planetoids, as an eminent astronomer, in a letter to me, suggested; or whether we admit them at once into the class of our old seven large planets. In the latter case, however, we must recollect, that if we would speak with precision,

* See Phil. Trans. for 1802, p. 477.

they should be called very small, and exzodiacal; for, the great inclination of the orbit of one of them to the ecliptic, amounting to 35 degrees, is certainly remarkable. That of the other is also considerable; its latitude, the last time I saw it, being more than 15 degrees north. These circumstances, added to their smallness, show that there exists a greater variety of arrangement and size among the bodies which our sun holds in subordination, than we had formerly been acquainted with, and extend our knowledge of the construction of the solar, or insulated sidereal system. It will not be required that I should add any thing farther on the subject of this first article of my classification; I may therefore immediately go to the second, which treats of binary sidereal systems, or real double stars.

We have already shewn the possibility that two stars, whatsoever be their relative magnitudes, may revolve, either in circles or ellipses, round their common centre of gravity; and that, among the multitude of the stars of the heavens, there should be many sufficiently near each other to occasion this mutual revolution, must also appear highly probable. But neither of these considerations can be admitted in proof of the actual existence of such binary combinations. I shall therefore now proceed to give an account of a series of observations on double stars, comprehending a period of about 25 years, which, if I am not mistaken, will go to prove, that many of them are not merely double in appearance, but must be allowed to be real binary combinations of two stars, intimately held together by the bond of mutual attraction.

It will be necessary to enter into a certain theory, by which these observations ought to be examined, that we may find to what cause we should attribute such changes in the position, or

distance, of double stars, as will be reported; and, in order to make the required principles very clear, I shall give them in a few short and numbered sentences, that they may be referred to hereafter.

In Plate VII. Fig. 1, let us call the place of the sun, which may also be taken for that of the observer, O. In the centre of an orbit or plane N F S P is α Geminorum; and, if any other star is to be examined, we have only to exchange the letter α for that by which such double star is known. This letter is always understood to represent the largest of the two stars which make up the double star; and a general expression for its smaller companion will be x. N, F, S, P, represent the positions of the different parts of the heavens, with respect to α, north, following, south, and preceding; and the small letters n, f, s, p, stand for the same directions with respect to O. $x\,\alpha$ P, is the angle of position of the two stars x and α, with the parallel F P.

As the motion of an observer affects the relative situation of objects, we have three bodies to consider, in our investigation of the cause of the changes which will be pointed out; the sun, the large star, and the small star, or, as we have shortly called them, O, α, x. This admits of three cases: a motion of one of the three bodies; another, of two; and a third, of all the three bodies together. We shall now point out the consequences that will arise in each of the cases.

Single Motions.

No. 1. Motion of x. When α and O are at rest, the motion of x may be assumed, so as perfectly to explain any change of the distance of the two stars, and of their angle of position.

No. 2. Motion of α. When x and O are at rest, and α has a motion, either towards P, N, F, or S, then the effect of it, whatever may be the angle PαO, will be had by entering the following Table, with the direction of the given motion.

Motion.	Distance.	Angle.	Quadrants.
αP	$-$	$+$	1st and 4th
	$+$	$-$	2 — 3
αF	$+$	$-$	1 — 4
	$-$	$+$	2 — 3
αN	$-$	$-$	1 — 2
	$+$	$+$	3 — 4
αS	$+$	$+$	1 — 2
	$-$	$-$	3 — 4

No. 3. Motion of O. 1st case. When α and x are at rest, and the angle PαO is 90 degrees, a proper motion of O, towards either p, f, n, or s, which will be extremely small when compared with the distance of O from α, can have no effect on the apparent distance, or angle of position, of the two stars; and therefore no other motion, composed of the directions we have mentioned, will induce a change in the comparative situation of α and x.

2d case. When the plane PNFS is oblique to the ray αO, and the angle PαO more than 90 degrees, the effect of the motion of O will be had by the following Table.

Motion.	Distance.	Angle.	Quadrants.
O*p*	+	−	1st and 2d 3 — 4
O*f*	−	+	1 — 2 3 — 4
O*n*	+ −	+ −	1 — 3 2 — 4
O*s*	− +	− +	1 — 3 2 — 4

3d case. When the angle PαO is less than 90 degrees, the following Table must be used.

Motion	Distance.	Angle.	Quadrants.
O*p*	−	+	1st and 2d 3 — 4
O*f*	+	−	1 — 2 3 — 4
O*n*	− +	− +	1 — 3 2 — 4
O*s*	+ −	+ −	1 — 3 2 — 4

Double Motions.

No. 4. If we admit different motions in two of our three bodies, and if the ratio of the velocities, the directions of the

motions, and the ratio of the distances of the bodies be given quantities, a supposition in which we admit their concurrence, may explain the phenomena of a double star, but can never be probable.

Motions of the three Bodies.

No. 5. If we admit different motions in every one of the three bodies, O, α, x, and if the velocities and directions of the motions, as well as the relative distances of the three bodies are determined, an hypothesis which admits the existence of such motions and situations, may resolve the phenomena of a double star, but cannot have any pretension to probability.

The compass of this Paper will not allow me to give the observations of my double stars at full length; I shall therefore, in the examination of every one of them, only state those particulars which will be required for the purpose of investigating the cause of the changes that have taken place, either in the distance, or angle of position, of the two stars of which the double star is composed.

As the arguments in the case of most of these stars will be nearly the same, it may be expected, that the first two or three which are to be examined will take up a considerable space; and the number of double stars, in which I have already ascertained a change, amounting to more than fifty, it will not be possible to give them all in one paper; I shall therefore confine the present one to a moderate length, and leave it open for a continuation at a future opportunity.

α Geminorum.

From my earliest observations on the distance of the two stars which make up the double star in the head of Castor, given in the first of my catalogues of double stars, we find, that about 23 years and a half ago, they were nearly two diameters of the large star asunder. These observations have been regularly continued, from the year 1778 to the present time, and no alteration in the distance has been perceived: the stars are now still nearly 2 diameters of the large one asunder.

It will be necessary to enter a little into the practicability of ascertaining distances by a method of estimation apparently so little capable of precision. From a number of observations and experiments I have made on the subject, it is certain that the apparent diameter of a star, in a reflecting telescope, depends chiefly upon the four following circumstances: the aperture of the mirror with respect to its focal length; the distinctness of the mirror; the magnifying power; and the state of the atmosphere at the time of observation. By a contraction of the aperture, we can increase the apparent diameter of a star, so as to make it resemble a small planetary disk. If distinctness should be wanting, it is evident that the image of objects will not be sharp and well defined, and that they will consequently appear larger than they ought. The effect of magnifying power is, to occasion a relative increase of the vacancy between two stars that are very near each other; but the ratio of the increase of the distance is not proportional to that of the power, and sooner or later comes to a maximum. The state of the atmosphere is perhaps the most material of the four conditions, as we have it not in our power to alter it. The effects of moisture, damp air, and

haziness, (which have been related in a paper where the causes that often prevent the proper action of mirrors were discussed,) show the reason why the apparent distance of a double star should be affected by a change in the atmosphere. The alteration in the diameter of Arcturus, extending from the first to the last of the ten images of that star, in the plate accompanying the abovementioned paper,* shows a sufficient cause for an increase of the distance of two stars, by a contraction of their apparent disks. A skilful observer, however, will soon know what state of the air is most proper for estimations of this kind. I have occasionally seen the two stars of Castor, from $1\frac{1}{2}$ to 2 and $2\frac{1}{2}$ diameters asunder; but, in a regular settled temperature and clear air, their distance was always the same. The other three causes which affect these estimations, are at our own disposal; an instance of this will be seen in the following trial. I took ten different mirrors of 7 feet focal length, each having an aperture of 6,3 inches, and being charged with an eye-glass which gave the telescope a magnifying power of 460. With these mirrors, one after another, the same evening, I viewed the two stars of our double star; and the result was, that with every one of them, the stars were precisely at an equal distance from each other. These mirrors were all sufficiently good to show minute double stars well; and such a trial will consequently furnish us with a proper criterion, by which we may ascertain the goodness of our telescope, and the clearness of the atmosphere required for these observations. To those who have not been long in the habit of observing double stars, it will be necessary to mention, that, when first seen, they will appear nearer together than after a certain time; nor is it so soon as might be

* See Phil. Trans. for 1803, page 232, Plate III.

expected, that we see them at their greatest distance. I have known it to take up two or three months, before the eye was sufficiently acquainted with the object, to judge with the requisite precision.

Whatever may be the difficulties, or uncertainties, attending the method of determining the distance of two close stars by an estimation of the apparent diameter, it must however be confessed, that we have no other way of obtaining the same end with so much precision. Our present instance of α Geminorum, will show the degree of accuracy of which such estimations are capable, and at the same time prove, that the purpose for which I shall use the estimated interval between the two stars will be sufficiently answered. By an observation of the 10th of May, 1781, we have the diameter of the largest of the two stars to that of the smallest as 6 to 5; and, according to several measures I have taken with the micrometer, we may admit their distance, diameters included, to be five seconds. Then, as the vacancy between the two stars is nearly, but not quite, 2 diameters of the large one, I shall value it at $1\frac{1}{2}$. From this we calculate, that the diameter of the large star, under the circumstances of our estimation, is nearly 1″,85: so that an error of one quarter of such a diameter, which is the most we can admit, will not exceed 0″,84. Nor is it of much consequence, if the measure of 5″ should not be extremely correct; as a small mistake in that quantity will not materially affect the error of estimation by the diameter, which, from what has been said, if the measure was faulty to a second, would not amount to more than one-fifteenth part of it.

Having thus ascertained that no perceptible change in the distance of the stars has taken place, we are now to examine

the angle of position. In the year 1779, it was 32° 47′ north preceding; and, by a mean of the three last measures I have taken, it is now only 10° 53′. In the space of about 23 years and a half, therefore, the angle of position has manifestly undergone a diminution, of no less than 21° 54′; and, that this change has been brought on by a regular and gradual decrease of the angle, will be seen when the rest of the measures come to be examined.

The accuracy of the micrometer which has been used, when the angles of position were taken, being of the utmost importance, it becomes necessary to ascertain how far it will be safe to rely on the result of the measures. It might be easily shown that, in the day time, a given angle, delineated on a card, and stuck up at a convenient distance, may be full as accurately measured by a telescope furnished with this micrometer, as it can be done by any known method, when the card is laid on a table before us; but this would not answer my purpose. For, objects in motion, like the stars, especially when at a distance from the pole, cannot be measured with such steadiness as those which are near us, and at rest. The method of illuminating the wires, and other circumstances, will likewise affect the accuracy of the angles that are measured, especially when the distance of the stars is very small. I shall therefore have recourse to astronomical observations, in order to see what the micrometer has actually done.

January 22, 1802. The position of A Orionis was taken. 1st measure, 52° 38′ south preceding; 2d measure, 54° 14′. Mean of the two measures, 53° 26′. Deviation of the measures from the mean, 48′.

March 4, 1802. 11 Monocerotis. 1st measure, 28° 18′ south

following; 2d measure, 26° 49′. Mean of the two, 27° 34′. Deviation from the mean, 45′.

February 9, 1803. α Geminorum. 1st measure, 6° 11′ north preceding; 2d measure, 4° 48′. Mean of the two, 5° 29′. Deviation from the mean, 41′.

September 6, 1802. η Coronæ. 1st measure, 89° 42′ north following; 2d measure, 89° 38′. Mean of the two, 89° 40′. Deviation from the mean, 2′.

When these observations are considered, we shall not err much if we admit that, in favourable circumstances, and with proper care, the micrometer, by a mean of two measures, will give the position of a double star true to nearly one degree; but, as the opportunities of taking very accurate measures are scarce, it will be necessary to have recourse to some more discordant observations.

February 18, 1803. β Orionis. 1st measure, 72° 58′ south preceding; 2d measure, 67° 24′. Mean of the two, 70° 11′. Deviation from the mean, 2° 47′.

But a memorandum to the observation says, that the evening was not favourable. We may therefore admit, that in the worst circumstances which can be judged proper for measuring at all, an error in the angle of position by two measures will not amount to three degrees.

It will be remarked, when we come to compare single measures which have been taken on different nights, that they are somewhat more discordant; but I have not ventured to reject them on that account, except in cases where it was pretty evident that some mistake in reading off, or other accident to which all astronomical observations are liable, was to be apprehended. Nor can such disagreements materially affect the

conclusions I have drawn, when it appears that the deviations happen sometimes to be on one side, and sometimes on the other side, of the true angle of position. For, since that angle is not a thing that will change in the course of a few nights, the excess of one measure will serve to correct the defect of another; and we are not to think it extraordinary, when stars are so near together, and their motion through the field of view (in consequence of the high magnifying power we are obliged to use) so quick, that we should now and then even fall short of that general accuracy which may be had by a careful use of the micrometer.

I shall now enter into an examination of the cause of the change in the angle of position of the small star near Castor.

A revolving star, it is evident, would explain in a most satisfactory manner, a continual change in the angle of position, without an alteration of the distance. But this, being a circumstance of which we have no precedent, ought not to be admitted without the fullest evidence. It will therefore be right to examine, whether the related phenomena cannot be satisfactorily explained by the proper motions of the stars, or of the sun.

Single Motions.

(a) The three bodies we have to consider, are O, α, and x; and, supposing them to be placed as they were observed to be in the year 1779; the angle $x \alpha$ P, in Fig. 1, will be 32° 47′ north preceding. We are at liberty to let the angle P α O be what will best answer the purpose. Then, in order to examine the various hypotheses that may be formed, according to the arrangement of the principles we have given, we shall begin with No. 1; and, as this admits that all phenomena may be

resolved by a proper motion of x, let us suppose this star to be placed any where far beyond α, but so as to have been seen, in the year 1779, where the angle of position, 32° 47′ north preceding, and the observed distance, near 2 diameters of the large star, required it. With a proper velocity, let it be in motion towards the place where it may now be seen at the same distance from Castor, but under an angle of position only 10° 53′ north preceding. It may then be admitted, that a small decrease of the distance which would happen at the time when the angle of position was 21° 50′, could not have been perceived; so that the gradual change in the observed angle of position, as well as the equality of the distance of the two stars, will be sufficiently accounted for. But the admission of this hypothesis requires, that α Geminorum and the solar system should be at rest; and, by the observations of astronomers, which I shall soon have occasion to mention, neither of these conditions can be conceded.

(b) If, according to No. 2, we admit the motion of α, we shall certainly be more consistent with the observations which astronomers have made on the proper motion of this star;* and, as a motion of the solar system, which I shall have occasion to mention hereafter, has not been rigidly proved, it may, for the sake of argument, be set aside; nor has a proper motion of the star x been any where ascertained. The retrograde annual proper motion of Castor, in right ascension, according to Dr. Maskelyne, is 0″,105. This, in about 23½ years, during which

* See Tobiæ Mayeri *Opera inedita*. *De motu fixarum proprio*, page 80. Also Dr. Maskelyne's first Volume of Observations. Explanation and Use of the Tables, page iv. Or Mr. Wollaston's Astronomical Catalogue, end of the Preface. Likewise *Connoissance des Temps pour l'Année* VI. page 203. *Sur le Mouvement particulier propre a différentes Etoiles*; par Mons. De la Lande.

time I have taken notice of the angle of position and distance of the small star, will amount to a change of nearly 2″,47. Then, if we enter the short Table I have given in No. 2, with the motion αP, we find, that in the first quadrant, where the small star is placed, the distance between the two stars will be diminished, and the angle of position increased. But since it appears, by my observations, that the distance of the stars is not less now than it was in 1780; and that, instead of an increase in the angle of position, it has actually undergone a diminution of nearly 22 degrees; it follows, that the motion of α Geminorum in right ascension, will not explain the observed alterations in the situation of this double star. If, according to Mr. DE LA LANDE's account,* we should also consider the annual proper motion of α in declination, which is given 0″,12 towards the north, we shall find, by entering our Table with the motion αN, amounting to 2″82, that the distance of the two stars will be still more diminished; but that, on the contrary, the angle of position will be much lessened; and, by combining the two motions together, the apparent disks of the two stars should now be a little more than one-tenth of a second from each other, and the angle of position 35 degrees south preceding. But, since neither of these effects have taken place, the hypothesis cannot be admitted.

(c) That the sun has a proper motion in space, I have shown with a very high degree of evidence, in a paper which was read at the Royal Society about twenty years ago.† The same opinion was before, but only from theoretical principles, hinted at by Mr. DE LA LANDE, and also by the late Dr. WILSON, of

* See page 211 of the treatise before referred to.

† See Phil. Trans. Vol. LXXIII. page 247.

Glasgow;* and has, since the publication of my paper, been taken up by several astronomers,† who agree that such a motion exists. In consequence of this, let us now, according to No. 3, assign to the sun a motion in space, of a certain velocity and direction. Admitting therefore α and x to be at rest, let the angle PαO be 90 degrees; then, by the 1st case of No. 3, we find that none of the observed changes of the angles of position will admit of an explanation. There is moreover an evident concession of the point in question, in the very supposition of the above angle of 90 degrees; for, if x be at the same distance as α from the sun, and no more than 5″ from that star, its real distance, compared to that of the sun from the star, will be known; and, since that must be less than the 40 thousandth part of our distance from Castor, these two stars must necessarily be within the reach of each other's attraction, and form a binary system.

(d) Let us now take the advantage held out by the 2d case of No. 3, which allows us to place x far behind α; in which situation, the angle PαO will be more than 90 degrees. The star x being less than α, renders this hypothesis the more plausible. Now, as a motion of Castor, be it real or apparent, has actually been ascertained, we cannot set it aside; the real motion of O, therefore, in order to account for the apparent one of α, must be of equal velocity, and in a contrary direction; that is, when decomposed, 0″,105 towards f, and 0″,12, towards s. The effect of the sun's moving from O towards f, according to

* See my note in Phil. Trans. Vol. LXXIII. page 283.

† See *Astronomisches Jahrbuch für das Jahr* 1786; *seite* 259. *Über die fortrückung unseres Sonnen-Systems, von* Herrn *Professor* Prevost. *Und für das Jahr* 1805; *seite* 113.

the 1st Table in No. 3, is, that the distance between the two stars will be diminished, and the angle of position increased. But these are both contrary to the observations I have given. The motion of O in declination towards *s*, according to the same Table, will still diminish the distance of the two stars, but will also diminish the angle of position. Then, since a motion in right ascension increases the angle, while that in declination diminishes it, the small star may be placed at such a distance that the difference in the parallax, arising from the solar motion, shall bring the angle of position, in $23\frac{1}{2}$ years, from 32° 47′ to 10° 53′; which will explain the observed change of that angle. The distance of the star *x*, for this purpose, must be above $2\frac{1}{3}$ times as much as that of α from us. But, after having in this manner accounted for the alteration of the angle of position, we are, in the next place, to examine the effect which such a difference of parallax must produce in the apparent distance of the two stars from each other. By a graphical method, which is quite sufficient for our purpose, it appears, that the union of the two motions in right ascension and declination, must have brought the two stars so near, as to be only about half a diameter of the large star from each other; or, to express the same in measures, the centres of the stars must now be 1″,8 nearer than they were $23\frac{1}{2}$ years ago. But this my observations cannot allow; for we have already shown, that any change of more than 3 or 4-tenths of a second must have been perceived.

If, on the other hand, we place the star *x* at such a distance that the solar parallax may only bring it about 4-tenths of a second nearer to α, which is a quantity we may suppose to have escaped our notice in estimating the apparent distance of the two stars, then will the angle of position be above 20 degrees

too large. This shows, that no distance, beyond Castor, at which we can place the star, will explain the given observations.

(e) The last remaining trial we have to examine, is to suppose x to be nearer than α; the angle PαO, will then be less than 90 degrees; and the effect of a motion of O towards f, by the 2d Table in No. 3, will be an increase of the distance of the two stars, and a diminution of their angle of position. But the motion Os, which is also to be considered, will add to the increase of the distance, and counteract the diminution of the angle. It is therefore to be examined, whether such an increase of distance as we can allow to have escaped observation, will explain the change which we know to have happened in the angle, during the last 23$\frac{1}{2}$ years. By the same method of compounding the two motions as before, it immediately appears, than we cannot place the small star more than about 1-tenth of the distance Oα on this side of Castor, without occasioning such an increase of the apparent distance of the two stars as cannot possibly be admitted; and that, even then, the angle of position, instead of being less, will be a few degrees larger, at the end of 23$\frac{1}{2}$ years, than it was at the beginning. This hypothesis, therefore, like all the foregoing ones, must also be given up, as inconsistent with my observations.

It is moreover evident, that the observations of astronomers on the proper motion of the stars in general, will not permit us to assume the solar motion at pleasure, merely for the sake of accounting for the changes which have happened in the appearances of a double star. The proper motion of Castor, therefore, cannot be intirely ascribed to a contrary motion of the sun. For we can assign no reason why the proper motion of this star alone, in preference, for instance, to that of Arcturus,

of Sirius, and of many others, should be supposed to arise from a motion of the solar system. Now, if they are all equally intitled to partake of this motion, we can only admit it in such a direction, and of such a velocity, as will satisfy the mean direction and velocity of the general proper motions of the stars; and place all deviations to the account of a real proper motion in each star separately.

Double Motion.

(f) In order to explain the phenomena of our double star, according to No. 4, by the motion of two bodies, for instance α and x, it will be required that they both should move in given directions; that the velocities of their motions should be in a given ratio to each other; and that this ratio should be compounded with the ratio of their distances from O; a supposition which must certainly be highly improbable. To show this with sufficient evidence, let us admit that, according to the best authorities, the annual proper motion of Castor is $-0'',105$ in right ascension, and $0'',12$ in declination towards the north. Then, as the small star, without changing its distance, has moved through an angle of 21° 54′, the only difference in the two motions of these stars, will be expressed by the extent of the chord of that angle. To produce the required effect, it is therefore necessary that the motion of α, which is given, should regulate that of the small star, whose relative place at the end of $23\frac{1}{2}$ years is also given. Then, as α moves in an angle of 58° 31′ north preceding, and with a velocity which, being expressed by the space it would describe in $23\frac{1}{2}$ years, will be $3'',51$, it is required that x shall move in an angle of 89° 25′, likewise north preceding, and with a velocity of $3'',02$. The

ratio of the velocities, therefore, and the directions of the motions, are equally given. But this will not be sufficient for the purpose: their distance from O must also be taken into consideration. It has been shown, that the two stars cannot be at an equal distance from us, without an evident connection; it will therefore be necessary for those who will not allow this connection, to place one of them nearer to us than the other. But, as the motions which have been assumed, when seen from different distances, will subtend lines whose apparent magnitudes will be in the inverse ratio of the assumed distances, it is evident that this ratio, if the motions are given, must also be a given one; or that, if the distances be assumed, the ratio of the motions must be compounded with the ratio of the distances. How then can it be expected that such precise conditions should be made good, by a concurrence of circumstances owing to mere chance? Indeed, if we were inclined to pass by the difficulties we have considered, there is still a point left which cannot be set aside. The motion of the solar system, although its precise direction and velocity may still be unknown, can hardly admit of a doubt; we have therefore a third motion to add to the former two, which consequently will bring the case under the statement contained in our 7th number, and will be considered hereafter.

(g) If we should intend to change our ground, and place the two motions in O and x, it will then be conceded, that the motion of α is only an apparent one, which owes its existence to the real motion of the sun. By this, the effect of the solar parallax on any star at the same distance will be given; and it cannot be difficult to assume a motion in x, which shall, with the effect of this given parallax, produce the apparent motion, in the

direction of a chord from the first to the last angle of position pointed out by my observations; taking care, however, not to place the stars α and x at the same distance from us; and using the inverse ratio of the solar parallax as a multiple in the assigned motion. For instance, let the sun have a motion of the velocity expressed as before by 3″,51, and in a direction which makes an angle of 53° 31′ south following with the parallel of α Geminorum; and let the small star x have a real motion in an angle of 18° 40′ south preceding from the parallel of its situation, and with a real velocity which, were it at the distance of α, would carry it through 1″,89. Then, if the distance of the small star be to that of the large one as 3 to 2, the effect of the solar parallax upon it will be $\frac{2}{3}$ of its effect upon α; that is, while α, which is at rest, appears to move over a space of 3″,51, in an angle of 53° 31′ north preceding, the parallactic change of place in x will be 2″,34 in the same direction. This, though only an apparent motion, will be compounded with the real motion we have assigned to it, but which, at the distance of α, will only appear as 1″,26; and the joint effect of both will bring the star from the place in which it was seen 23½ years ago, to that where now we find it situated. α, in the same time, will appear to have had an annual proper motion of — 0″,105 in right ascension, and 0″,12 in declination towards the north; and thus all phenomena will be explained.

From this statement, we may draw a consequence of considerable importance. If we succeed, in this manner, in accounting for the changes observed in the relative situation of the two stars of a double star, we shall fail in proving them to form a binary system; but, in lieu of it, we shall gain two other points, of equal value to astronomers. For, as α Geminorum, according

to the foregoing hypothesis, is a star that has no real motion, its apparent motion will give us the velocity and direction of the motion of the solar system; and, this being obtained, we shall also have the relative parallax of every star, not having a proper motion, which is affected by the solar motion. Astronomical observations on the proper motion of many different stars, however, will not allow us to account for the motion of α Geminorum in the manner which the foregoing instance requires; the hypothesis, therefore, of its being at rest, must be rejected.

(*b*) If we place our two motions in O and α, we shall be led to the same conclusion as in the last hypothesis. The known proper motion of α, and the situations of the small star in 1779 and 1803, given by my observations, will ascertain the apparent motion of x, now supposed to be at rest. Then, since the change in the place of x must be intirely owing to the effect of parallax, it will consequently give us, in the same manner as before, the quantity and direction of the motion of the solar system, and the relative distances of all such stars as are affected by it. But, here again, the solar motion required for the purpose is such as cannot be admitted; and the hypothesis is not maintainable.

Motion of the three Bodies.

(*i*) There is now but one case more to consider, which is, according to No. 5, to assign real motions to all our three bodies; and this may be done as follows. Suppose the sun to move towards λ Herculis, with the annual velocity 1.

Let the apparent motion of α Geminorum be as it is stated in the astronomical tables before mentioned; but suppose it to arise from a composition of its real motion with the effect of the

systematical parallax, as we may call that apparent change of place of stars which is owing to the motion of the solar system. Let the real motion of x, aided by the effect of the same parallax, be the cause of the changes in the angle of position which my observations have given. We may admit the largest of the two stars of our double star to be of the second magnitude; and, as we are not to place x too near α, we may suppose its distance from O to be to that of α from the same as 3 to 2. In this case, O will move from the parallel of α, in an angle of 60° 37′ north following, with an apparent annual velocity of ,4536. The motion of α in right ascension, may be intirely ascribed to solar parallax; but its change of declination, cannot be accounted for in the same manner. Let us therefore admit that the solar velocity, in the direction we have calculated, will produce an apparent retrograde motion in α, which, in $23\frac{1}{2}$ years will amount to 2″,085 in right ascension. But the same parallax will also occasion a change in declination, towards the south preceding, of 3″,701; and, as this will not agree with the observed motion of α, we must account for it by a proper motion of this star directly towards the north. The real annual velocity required for this purpose, must be 1,3925.

The apparent motion of x, by parallax, at the distance we have placed this star, will be 2″,832 towards the south preceding; and, by assigning to it an annual proper motion of the velocity 1,3354, in the direction of 73° 10′ north preceding its own parallel, the effect of the solar parallax and this proper motion together, will have caused the small star, in appearance, to revolve round α, so as to have produced all the changes in the angle of position which my observations have given; and, at the same time, α will have been seen to move from its former

place, at the annual rate of 0″,105 in right ascension, and 0″,19 in declination towards the north.

In this manner, we may certainly account for the phenomena of the changes which have taken place with the two stars of α Geminorum. But the complicated requisites of the motions which have been exposed to our view, must surely compel every one who considers them to acknowledge, that such a combination of circumstances involves the highest degree of improbability in the accomplishment of its conditions. On the other hand, when a most simple and satisfactory explanation of the same phenomena may be had by the effects of mutual attraction, which will support the moving bodies in a permanent system of revolution round a common centre of gravity, while at the same time they follow the direction of a proper motion which this centre may have in space, it will hardly be possible to entertain a doubt to which hypothesis we ought to give the preference.

As I have now allowed, and even shown, the possibility that the phenomena of the double star Castor may be explained by proper motions, it will appear that, notwithstanding my foregoing arguments in favour of binary systems, it was necessary, on a former occasion, to express myself in a conditional manner,* when, after having announced the contents of this Paper, I added, "*should these observations be found sufficiently conclusive;*" for, if there should be astronomers who would rather explain the phenomena of a small star appearing to revolve round Castor by the hypothesis we have last examined, they may certainly claim the right of assenting to what appears to them most probable.

I shall now enter into a more detailed examination of the

* See Phil. Trans. for 1802, page 486.

several angles of position I have taken at different times, and show that they agree perfectly well with the appearances which must arise from the revolution of a small star round Castor. A calculation of these angles may be had, by finding the annual motion of the small star, from the change of 21° 54′, which has been shown to have taken place in 23 years and 142 days. Accordingly, I have given, in the 1st column of the following Table, the time when the angles were taken. In the 2d, are the angles as they were found by measure; they are all in the north-preceding quadrant. The 3d column contains a calculation from the annual motion of 56′,18, obtained as before mentioned: it shows what these angles should have been, according to our present supposition of a revolving star. And the last column gives the difference between the observed and calculated angles.

Times of the observations.	Observed angles.	Calculated angles.	Differences.
Nov 5, 1779 - -	32° 47′	32° 47′	0° 0′
Feb. 23, 1791 - -	22 57	22 11	+ 0 46
Feb. 26, 1792 - -	27 16	21 16	+ 6 0
Dec. 15, 1795 - -	13 52	17 42	— 3 50
March 26, 1800 - -	18 8	13 41	+ 4 27
April 23, 1800 - -	10 30	13 37	— 3 7
Dec. 31, 1801 - -	7 58	12 2	— 4 4
Jan. 10, 1802 - -	10 53	12 1	— 1 8
Jan. 23, 1802 - -	10 28	11 59	— 1 31
Feb. 28, 1802 - -	13 0	11 53	+ 1 7
Feb. 11, 1803 - -	7 53	11 0	— 3 7
March 23, 1803 - -	13 23	10 54	+ 2 29
March 27, 1803 - -	10 53	10 53	0 0

On looking over the 4th column of this table, it will be found, that the differences between the observed and calculated angles are not greater than may be expected, considering that most of the early measures are single, and cannot have the accuracy which may be obtained by repetition. Even as they are, we must acknowledge them sufficient to ascertain the gradual change in the angle of position of the two stars. In one place, the difference amounts to six degrees; but it will soon appear, that a more accurate annual motion gives a calculated position which takes off much of the error of this measure.

In a conversation with my highly esteemed friend the Astronomer Royal, he happened some time ago accidentally to mention, that Dr. BRADLEY had formerly observed the two stars of α Geminorum to stand in the same direction with Castor and Pollux. It occurred to me immediately, that if the time of this observation could be nearly ascertained, it would be of the greatest importance to the subject at present under consideration. For, should Dr. BRADLEY's position be very different from a calculated one, it would induce us at once to give up the idea of a revolving star. The observation was made by Dr. BRADLEY with a view to see whether any change could be perceived in the course of the year, by which the annual parallax of the stars might be discovered. Dr. MASKELYNE, who had this information from Dr. BRADLEY in conversation, had made a memorandum of it in his papers. He has been so kind as to look for it; and, as soon as he found the note, he sent me the following copy, which I have his permission to transcribe.

"*Double star Castor. No change of position in the two Stars:* "*the line joining them, at all times of the year, parallel to the line*

"*joining Castor and Pollux in the heavens, seen by the naked*
"*eye.*"

Dr. MASKELYNE informs me, that the observation must have been made about the year 1759; and also mentions, that he himself verified the fact, as to the line joining the two stars appearing through the telescope parallel to the line joining Castor and Pollux, in 1760 or 1761; but that he did not examine it at various times of the year.

The advantage of having an angle of position observed in 1759 by Dr. BRADLEY, and so soon after verified by Dr. MASKELYNE, will give us an addition of 20 years to our period. On calculating the right ascension and polar distance of Castor and Pollux for November 5, 1759, it appears, that a line drawn from Pollux through Castor, must have made an angle of 56° 32′ north preceding with the parallel of that star; and, this being also the position of our double star, we have an interval of 43 years and 142 days, for a change of 45° 39′, from the time of Dr. BRADLEY's observation to that of my last measure of the angle. By this we are now enabled to correct our former calculation, which was founded upon a supposition that the first angle of position I had taken was perfect; but this could hardly be expected, and on examination it appears that the measure was 2° 40′ too little. The annual motion, by our increased period, is 1° 3′,1; and the computation of the angles of position in the 3d column of the following Table, as well as the differences contained in the 4th, are made according to this motion.

Times of the observations.	Observed angles.	Calculated angles.	Differences.
Nov. 5, 1759 - -	56° 32′	56° 32′	0° 0′
Nov. 5, 1779 - -	32 47	35 29	— 2 42
Feb. 23, 1791 - - -	22 57	23 36	— 0 39
Feb. 26, 1792 - -	27 16	22 32	+ 4 44
Dec. 15, 1795 - -	18 52	18 32	— 4 40
March 26, 1800 - -	18 8	14 3	+ 4 5
April 23, 1800 - - -	10 30	13 58	— 3 28
Dec. 31, 1801 - -	7 58	12 12	— 4 14
Jan. 10, 1802 - - -	10 53	12 10	— 1 17
Jan. 23, 1802 - -	10 28	12 7	— 1 39
Feb. 28, 1802 - - -	13 0	12 1	+ 0 59
Feb. 11, 1803 - -	7 53	11 1	— 3 8
March 23, 1803 - - -	13 23	10 54	+ 2 29
March 27, 1803 - -	10 53	10 53	0 0

When the result of this Table is compared with that of the former, it will be seen that my observations agree not only very well with Dr. BRADLEY's position, but even give more equally divided differences than before, so that the excess and differences counteract each other better than in the first Table.

The time of a periodical revolution may now be calculated from the arch of 45° 39′, which has been described in 43 years and 142 days. The regularity of the motion gives us great reason to conclude, that the orbit in which the small star moves about Castor, or rather, the orbits in which they both move round their common centre of gravity, are nearly circular, and at right angles to the line in which we see them. If this should be nearly true, it follows, that the time of a whole apparent

revolution of the small star round Castor, will be about 342 years and two months.

γ Leonis.

Our foregoing discussions will greatly abridge the arguments which may be used, to show that this star and its small companion are also probably united in forming a binary system. But, in order to give more clearness to our disquisition, we shall follow the arrangement which has been used with α Geminorum, and prefix the same letters to our paragraphs. Then, if any one article should appear to be not sufficiently explained, we need but turn back to our first double star, where the same letter will point out what has already been said more at large on the subject; and an application of it may easily be made.

The distance of the stars γ and *x*, as I shall again call the small one, has undergone a visible alteration in the last 21 years. The result of a great number of observations on the vacancy between the two stars, made with the magnifying powers of 278, 460, 657, 840, 932, 1504, 2010, 2589, 3168, 4294, 5489, and 6652, is, that with the standard power and aperture of the 7-feet telescope, the interval in 1782 was $\frac{1}{4}$ of a diameter of the small star, and is now $\frac{1}{2}$. With the same telescope, and a power of 2010, it was formerly $\frac{1}{2}$ of a diameter of the small star, and is now full 1 diameter. In the years 1795, 1796, and 1798, the interval was found to have gradually increased; and all observations conspire to prove, that the stars are now $\frac{1}{2}$ a diameter of the small one farther asunder than they were formerly. The proportion of the diameter of γ to that of *x*, I have, by many observations, estimated as 3 to 4.

The first measured angle in 1782, is 7° 37′ north following;*

* In my second Catalogue of double Stars, (Phil. Trans. for 1785, page 48,) the

and the last, which has been lately taken, is 6° 21′ south following. The sum of these angles gives 15° 58′, for the change that has taken place in 21 years and 38 days. To account for this, we are to have recourse, as before, to the various motions of the three bodies.

Single Motions.

(*a*) The motion of x alone cannot be admitted, since it is known that γ Leonis is not at rest. The annual proper motion of this star, according to M. De la Lande, is + 0″,98 in right ascension, and 0″,04 in declination towards the south.

(*b*) γ cannot be the only moving body; because its motion in right ascension only, which, in 21,1 years, at the parallel of γ, amounts to 7″,49, would have long ago taken it away from the small star.

(*c*, *d*, *e*,) The sun cannot be the only moving body; because its motion in right ascension will not account for that of γ Leonis, which star therefore cannot be at rest. And, if we were willing to give up the former assumed solar motion, in order to fix upon such a one as would explain the motion of γ, we should be under a necessity to contradict the united evidence of the proper motions of many principal stars which are in opposition to it.

Double Motions.

(*f*) When two motions are proposed, we cannot fix upon γ and x for the moving bodies, unless we should set aside the solar motion, and this, we know, cannot properly admit of a doubt.

angle of position is 5° 24′. This was taken April 18, 1783; and, not being acquainted with the motion of the small star, I supposed it to be more accurate than the former measure.

(*g*) That we cannot allow O and x to be the two bodies in motion, follows from the insufficiency of the solar motion to account for that of γ, which must be real, or at least partly so.

(*h*) If O and γ are the moving bodies, the given situations of x, in the years 1782 and 1783, point out an apparent motion of x, which must be intirely owing to the solar parallax; and, therefore, those who will admit this hypothesis, must grant the discovery of the motion of the solar system, and of the proportional parallax of the two stars γ and x. Let us however examine whether any motion of the sun, such as we can admit, will account for the change of position and distance pointed out by my observations of the small star near γ Leonis.

The joint effect of proper motion and parallax, has carried γ from its situation in 1782 to that where we now find it. The small star, having all this time, in appearance, accompanied γ, must have gone through a space of 7″,98, in a direction which makes an angle of 8° 30′ south following with the parallel of γ, in order to be at its present distance from it, and at the same time to have undergone the required change of its angle of position. Now, as the supposition we are examining requires this small star to be actually at rest, it will be necessary to assign to the sun an opposite motion of the same velocity, in order to make that of x only an apparent one. The consequence of this will be a retrograde motion of the sun, which it is well known cannot be admitted.

Motion of the three Bodies.

(*i*) A motion of all the three bodies, is the only way left to explain the phenomena of our double star; and I shall now again point out the very particular circumstances which it is

requisite should all happen together, to produce the intended effect.

Let the motion of the sun, with the same annual velocity 1, as in the case of α Geminorum, be directed towards λ Herculis. Then the effect of this motion will show itself at the place of γ Leonis, in the annual velocity of ,3314, and in a direction which makes an angle of 31° 11′ south preceding with the parallel of that star. In this calculation, I have admitted the distance of the largest of the two stars of γ from the sun to be 3, that of α Geminorum being 2. But, if any other distance should hereafter be considered as more probable, the calculation may be easily adapted to it. The consequence of the parallax thus produced on γ Leonis in 21,1 years, will be an apparent motion of 2″,788 south preceding, in the abovementioned direction; and, on x, it will be in the same time, and in the same direction, 1″,091. As the small star must not be too near γ, we have, in the calculation, supposed it to be at the distance of 4 from O.

The real annual proper motion of γ is required to be 3,5202; and its direction must make an angle of 3° 40′ north following with the parallel. By this motion alone, γ would have passed over a space of 9″87 in 21,1 years; but, when it is combined with the apparent motion arising from parallax, the star will come into its present situation.

The real annual motion of x must be 4,6294, in a direction 0° 20′ south following. This will carry it over 9″,74, in 21,1 years; and, when combined with the apparent motion which the solar parallax will occasion, both together will bring it to its proper distance from γ Leonis, and to a situation which will agree with the last observed angle of position.

From what has been said, it is again evident, that not only as

many particular circumstances must concur in explaining the phenomena of γ Leonis as we have pointed out with α Geminorum, but that a very marked condition is added in our second double star, which requires an adjustment of velocities in γ and x, which shall also fit the same solar motion that was used in α Geminorum. And this proves, that every additional double star which requires the same condition in order to have its appearances explained, will inforce the arguments which have been used, in a compound ratio.

If, on the other hand, we have recourse to the simplicity of the known effects of attraction, and admit the two stars of our present double star to be united in one system, all the foregoing difficulties of accounting for the observed phenomena will vanish. Whatever may be the proper motion of the sun, the parallax arising from that cause will affect both stars equally, on account of their equal distance from the sun. The proper motion of γ Leonis also may be in any direction, and of any given velocity, such as will agree best with astronomical observations; since the motion of a system of bodies will not interfere with the particular motion of the bodies that belong to it, so that our secondary star will continue its revolution round the primary one without disturbance.

It will now be necessary to examine the observed angles of position, and to compare them with calculated ones; but, as there has been a change in the distance of the two stars, it is evident that, if they revolve in circular orbits, the situation of the plane of their revolution must be considerably inclined to the line in which we see the principal star.

Let NFSP, Fig. 2, be the orbit in which x revolves about γ placed in the centre. Suppose a perpendicular to be erected at

γ leading to O, not expressed in the figure. By an observation of Feb. 16, 1782, we have the angle $F\gamma x = 7° 37'$ north following; and the proportion of the apparent diameter of γ to that of x has been given as 5 to 4. It has also been ascertained, that the vacancy between the apparent diameters, when the first angle of position was taken, was $\frac{1}{4}$ diameter of the small star; and the last angle of position being $6° 21'$ south following, with a distance between the stars of $\frac{3}{4}$ diameter of the small star, we obtain the two points or centres of the small stars xx', through which an ellipsis $abxx'cd$ may be drawn about γ. This will be the apparent orbit in which the small star will be seen to move about γ, by an eye placed at O. And the inclination of the orbit to the line in which we see the double star, will be had sufficiently accurate to enable us to give a calculation of the several angles of position that have been taken. The ellipsis we have delineated shows that the small star, in its first situation x, could not be much past its conjunction at b, and that, consequently, in passing from x to x', the parts of the apparent elliptical arch, which are projections of the real circular arch bb', would be described in times nearly proportional to the time in which the whole arch has been described. Upon these principles, the 3d column of the following Table has been calculated.

Times of the observations.	Observed angles.	Calculated angles.	Differences.
Feb. 16, 1782 - -	7° 37′ *nf*	7° 37′	0° 0′
April 18, 1783 - -	5 24 *nf*	6 51	— 1 27
Jan. 24, 1800 - -	3 16 *sf*	4 15	— 0 59
Feb. 19, 1800 - -	3 23 *sf*	4 18	— 0 55
March 26, 1800 - -	3 47 *sf*	4 22	— 0 35
Jan. 26, 1802 - -	6 4 *sf*	5 35	+ 0 29
Feb. 10, 1803 - -	3 33 *sf*	6 16	— 2 43
March 22, 1803 - -	6 32 *sf*	6 20	+ 0 12
March 26, 1803 - -	6 21 *sf*	6 21	0 0

The difference between the calculated and observed angles, contained in the 4th column of the preceding Table, is so little, that we may look upon the gradual change of these angles as established by observation; and we may form a calculated estimate of the time which will be taken up by the mutual revolution of the two stars. The apparent places $x\,x'$, being referred to their real ones, give the arch bb', which has been described in 21 years and 38 days; and this arch, seen from the centre γ, is about 6° 20′: it follows, that the length of a whole revolution of our small star round γ Leonis, will be about 1200 years.

ε *Bootis.*

This beautiful double star, on account of the different colours of the stars of which it is composed, has much the appearance of a planet and its satellite, both shining with innate but differently coloured light.

There has been a very gradual change in the distance of the two stars; and the result of more than 120 observations, with

different powers, is, that with the standard magnifier, 460, and the aperture of 6,3 inches, the vacancy between the two stars, in the year 1781, was $1\frac{1}{2}$ diameter of the large star, and that it now is $1\frac{3}{4}$. By some earlier observations, the vacancy was found to be considerably less in 1779 and 1780; but the 7-feet mirror then in use was not so perfect as it should have been, for the purpose of such delicate observations. By many estimations of the apparent size of the stars, I have fixed the proportion of the diameter of ε to that of x, as 3 to 2. August 31, 1780, the first angle of position measured 32° 19′ north preceding;* and, March 16, 1803, I found it 44° 52′, also north preceding: the motion, therefore, in 22 years and 207 days, is 12° 33′. It should also be noticed, that while the apparent motion of α Geminorum, and of γ Leonis, is retrograde, that of ε Bootis is direct.

A proper motion in this star, if it has any, is still unknown; our former arguments, therefore, cannot be applied to it, without some additional considerations; and, as many others of my double stars will stand in the same predicament, I shall give an outline of what may be said, to show that this, and probably many of the rest, are also binary systems.

Single Motions.

(*a*—*e*) If ε Bootis is a star in which no proper motion can be perceived, we may infer, from the highly probable motion of the solar system, that this star, which is of the 3d magnitude, and on that account within the reach of parallax, must have a real motion, to keep up with the sun, in order to prevent an

* The angle of position, in my first Catalogue of double Stars, Phil. Trans. for 1782, page 115, is 31° 34′ (it should be 54′) north preceding. This will be found to be a mean of the three first measures hereafter given in a Table of positions.

apparent change of place, which must otherwise have happened. In this case, no single motion can be admitted to explain the phenomena of our double star. But, if a real proper motion of ε Bootis should hereafter be ascertained, the arguments we have used in the case of γ Leonis, will lead to the same conclusion.

Double Motions.

(*f*) ε and *x* cannot be the moving bodies; and our former argument (*f*) will apply to every double star whatsoever.

(*g*) O and *x* cannot be alone in motion; for, if no motion in ε can be perceived, it must move in a similar manner with the sun, and none of the three bodies will be at rest. But, if its proper motion shall hereafter be found out, it must either be exactly the reverse of the solar motion, and therefore only an apparent one, or it will be more or less different. In the latter case, all the three bodies must be in motion; in the former, the exact quantity of the solar motion will be discovered, and the relative parallax of many stars may be had by observation.

(*b*) If O and ε are the two bodies in motion, and if at the same time no motion in ε can be perceived, then the apparent motion of *x* must be intirely owing to the different effect of the solar parallax on ε and *x*; but the effect of the solar parallax on *x*, can only be in a direction contrary to the motion of the sun, which, being north following the small star, whether it be nearer or farther from us than ε, must have an apparent motion towards the south preceding part of the heavens. But this is directly in opposition to my observation of the motion of the small star, which, these last 23 years, has been directed towards the north following.

Motion of the three Bodies.

(*i*) Let the motion of the sun be again towards λ Herculis; then, if no motion in ε Bootis be perceivable, it must move exactly like O. Highly improbable as it is, let it be admitted. Then, in addition to this extraordinary supposition, a third motion is also required for *x*, which, aided by the solar parallax, is to carry it likewise within a quarter of a diameter of ε, into the same place where, though unperceived, the large star has been carried by its own motion; that is, in order to be apparently at rest, the sun, ε Bootis, and its small companion, must all move exactly alike, setting aside the very little difference in the position and distance of the small star, which, in the whole, amounts to little more than 6-tenths of a second; than which, certainly nothing can be more improbable.

But, if ε shall hereafter be found not to have been at rest during the time of my observations upon it, then its place will be given; and, since also the situation of *x*, with respect to ε, is to be had from my angles of position and distances of the two stars, the case will be similar to that which has already been considered, in the paragraph (*i*), under the head of γ Leonis.

I may here add a remark with regard to ε Bootis, which will be applicable to several more of my double stars. In the milky-way, a multitude of small stars are profusely scattered, and their arrangement is very different from what we perceive in those parts of the heavens which are at a considerable distance from it. About ε Bootis, which is situated in what I have formerly called figuratively a nebulous part of the heavens,* there are, comparatively speaking, hardly any stars; and, that so

* See Phil. Trans. for 1784, page 449.

remarkable a star as ε should have a companion, seems almost to amount to a proof that this very companion is, as it appears to be, a connected star. The *onus probandi*, therefore, ought in justice to fall to the share of those who would deny the truth of what we may call a fact; and I believe the utmost they could do, would be to prove that we may be deceived; but they cannot show that this star has no connection with ε Bootis.

This argument will be much supported, when we consider that many of the double stars in the milky-way are probably such as have one of the scattered stars, nearly in the same line, at a great distance behind them. In this case, the two stars of the double star have no connection with each other; and the great number of them in the milky-way, is itself an indication of this effect of the scattered multitude of small stars. In the single constellation of Orion, for instance, we have no less than 43, pointed out by my catalogues; ten of which are of the first class, and yet have undergone no change of distance or position since I first perceived them. But, with apparently insulated stars, such as ε Bootis, the case is just the reverse.

If, in consequence of our former arguments, and the present remarks, we place ε Bootis among the stars which hold a smaller one in combination, we may delineate its orbit as in Plate VIII. Fig. 3.

Let PNFS represent a circle, projected into the elliptical orbit $axx'bcd$. ε is the large star; and xx' are the first and last measured north preceding situations of the small one, as given in the following Table.

Times of the observations.	Observed angles.	Calculated angles.	Differences.
August 31, 1780 -	32° 19′	33° 58′	— 1° 39′
March 13, 1781 - -	30 21	34 13	— 3 52
May 10, 1781 - -	33 1	34 18	— 1 17
Feb. 17, 1782 - -	38 26	34 40	+ 3 46
August 18, 1796 -	45 32	41 40	+ 3 52
Jan. 28, 1802 - -	49 18	44 19	+ 4 59
August 31, 1802 - -	46 47	44 36	+ 2 11
March 23, 1803 -	43 43	44 52	— 1 9
March 26, 1803 - -	44 52	44 52	0 0

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The real motion from b to b' is projected into that from x to x'; and, while the elliptical arch subtends an angle of 12° 33′, the circular one will be about 4° 50′.

From the figure of the orbit, we may conclude that the small star, in its first position, at x or b, was not more than between 30 and 40 years past its conjunction; and that, consequently, the parts of the arch xx', were nearly proportional to the times of their being described. The positions have been calculated upon this principle; but with some allowance for the first observed angle, which I suppose to have been a little too small; and, though the differences of the observed and calculated angles are pretty considerable, the observations are still sufficiently consistent to prove the gradual change of the situation of the small star.

The quantity of the change in 22 years and 207 days, will show that a periodical revolution cannot take up less than 1681 years. The real figure and situation of the orbit, with many other particulars, are still unknown; it is, therefore, unnecessary

to point out the uncertainties in which the investigation of the periodical time of the small star about ε Bootis must long remain involved.

ζ *Herculis.*

My observations of this star furnish us with a phenomenon which is new in astronomy; it is, the occultation of one star by another. This epoch, whatever be the cause of it, will be equally remarkable, whether owing to solar parallax, proper motion, or motion in an orbit whose plane is nearly coincident with the visual ray. My first view of this star, as being double, was July 18, 1782. With 460, the stars were then $\frac{1}{2}$ diameter of the small star asunder. The large star is of a beautiful bluish white; and the small one ash-coloured.

July 21, of the same year, I measured the angle of position, 20° 42′ north following. With the standard power, the distance of the stars remained as before. With 987, they were one full diameter of the small one asunder.

In the year 1795, I found it difficult to perceive the small star; however, in October of the same year, I saw it plainly double, with 460; and its position was north following.

Other business prevented my attending to this star till the year 1802, when I could no longer perceive the small star. Sometimes, however, I suspected it to be still partly visible; and, in September of the same year, with 460, the night being very clear, the apparent disk of ζ Herculis seemed to be a little lengthened one way. With the 10-feet telescope, and a power of 600, I saw the two stars of γ Coronæ very distinctly; and, having in this manner proved the instrument to act well, I directed it to ζ Herculis, and found it to have the appearance of a

lengthened, or rather wedge-formed star; after which, I took a measure of the position of the wedge.

Our temperature is seldom uniform enough to permit the use of very high powers; however, on the 11th of April, 1803, I examined the apparent disk, with a magnifier of 2140, and found it, as before, a little distorted; but there could not be more than about $\frac{1}{8}$ of the apparent diameter of the small star wanting to a complete occultation. Most probably, the path of the motion is not quite central; if so, the disk will remain a little distorted, during the whole time of the conjunction. Our present observations cannot determine which of the stars is at the greatest distance; but this will occasion no difference in the appearance; for, if the small star should be the nearest, its light will be equally lost in the brightness of the large one.

The observations I have made on this star, are not sufficient to direct us in the investigation of the nature of the motion by which this change is occasioned.

We may however be certain, that with regard to

Single Motions,

(a, b) Neither x nor ζ can be supposed to be the only moving bodies, without contradicting the highly probable arguments for the sun's motion.

(c, d) If we admit the sun to be the moving body, the stars ζ and x being at rest, we may calculate the effect of the solar parallax upon them, as follows. Let O move towards λ Herculis, with the annual velocity 1, as in the case of α Geminorum; then, from the situation and magnitude of the large star of ζ Herculis, which we will suppose 4m, the effect of the solar motion at ζ will be only ,0522; and, at x, supposed to be at the distance 5m,

it will be ,0418. This will show itself at the parallel of ζ in a direction of 25° 5′ north preceding, the solar motion being in the opposite direction south following. But this parallax will only produce, in 20 years and 10 months, an apparent change of 0″,444 in ζ, and of 0″,355 in x; and will separate the stars, instead of bringing them to a conjunction.

(e) A considerable advantage may be gained, by placing x at a little more than $\frac{1}{3}$ the distance of ζ from O. For as, in the abovementioned time, this would make the effect of parallax upon it 1″,18, a conjunction should now take place. But then the stars, though very near each other, would not be quite in contact; much less could one of them occasion an occultation of the other. The supposition also, that the small star should be only $\frac{1}{3}$ of the distance of the large one from us, is not very favourable to the hypothesis.

δ Serpentis.

This double star has undergone a very considerable change in the angle of position, but none in the distance of the two stars. The 5th of September, 1782, an accurate measure of the position was 42° 48′ south preceding; and February 7, 1802, it measured 61° 27′ south preceding. In 19 years and 155 days, therefore, the small star has moved, in a retrograde order, over an arch of 18° 39′.

Every argument, to examine the cause of this motion, which has been used with ε Bootis, in the paragraphs from (a) to (i), will completely apply to this star; from this we may conclude, that the most natural way of accounting for the observed changes, is to admit the two stars to form a binary system. In this case we calculate, with considerable probability, that the periodical

time of a revolution of the small star round δ Serpentis, must be about 375 years.

γ *Virginis.*

This double star, which has long been known to astronomers,* has undergone a visible change since the year 1780, when I first began my observations of it. The 21st of November, 1781, I measured the position of the two stars, which was 40° 44′ south following. The stars are so nearly equal, that I have but lately ascertained the following one to be rather larger than its companion; the position, therefore, ought now to be called north preceding. By a mean of three measures, that were taken on the 15th of April, 1803, the angle was 30° 20′ *np*.

The distance, as far as estimations by the diameter can determine, when the stars are so far asunder as these are, remains without alteration. May 21, 1781, they were 2½ diameters asunder; and, by estimations lately made, with the same instrument and power as were used 21 years ago, the stars are still at the same distance of 2½ diameters.

A very small proper motion in declination, of 0″,02 towards the south, has been assigned to this double star;† but the quantity is hardly sufficient for us to rely much upon the accuracy of the determination. I shall therefore rather consider γ Virginis as one of the stars of which we have no proper motion ascertained; and the arguments to which I shall refer, will consequently be those which have been given with ε Bootis.

The change of the angle of position, in the time of 21 years and 145 days, amounts to 10° 24′; from which we obtain the

* *Memoires de l'Academie des Sciences.* Ann. 1720.

† *Connoissance des Temps,* Année VI. page 213.

annual motion of 29′,16. The observed and calculated angles, with their differences, on which it will not be necessary to make any remarks, are in the following Table.

Times of the observations.	Observed angles.	Calculated angles.	Differences.
Nov. 21, 1781 - -	40° 44′	40° 44′	0° 0′
Jan. 29, 1802 - -	28 22	30 51	− 2 29
April 15, 1803 - -	30 20	30 20	0 0
May 28, 1803 - -	32 2	30 17	+ 1 45

As a confirmation of the accuracy of these observations, we may have recourse to a position of the same stars, deduced from the places of them, as they are given in MAYER's Zodiacal Catalogue. By two observations, reduced to the beginning of the year 1756, the preceding one was 8″,8 before the other in right ascension, and 5″,3 more north than that star. From this we calculate the position, which was 54° 21′ 37″ north preceding. The interval from the 1st of January, 1756, to the 21st of November, 1781, is 25 years and 325 days. When this is added to the period I have given, we have 47 years and 105 days, for a motion of 24° 2′. The annual motion, deduced from this lengthened period, which is 30′,5, differs less than $1\frac{1}{2}$ minute from that which has been calculated from my observations. With the assistance, therefore, of MAYER's observation, which greatly supports our calculation, we may conclude, that the two stars of γ Virginis revolve round each other in about 708 years.

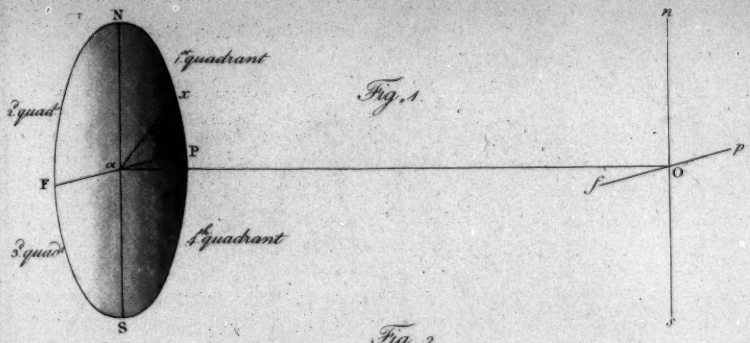
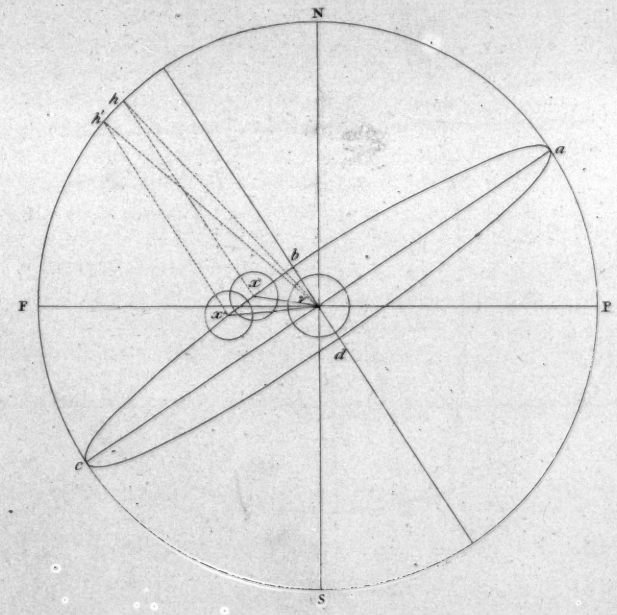

N
1st quadrant
2d quad
x
P
α
F
3d quad
4th quadrant
S
n
p
f
O
s

Fig. 1.

Fig. 2.


N
h
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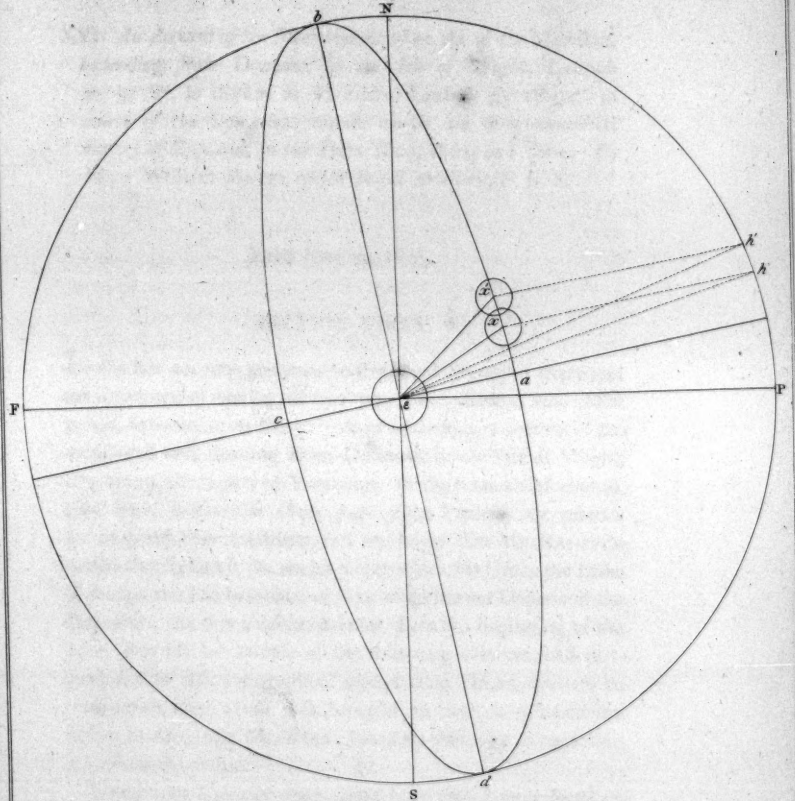
a
b
x
x'
r
F
P
d
c
S

Fig. 3.



XVI. *An Account of the Measurement of an Arc of the Meridian, extending from Dunnose, in the Isle of Wight, Latitude 50° 37′ 8″, to Clifton, in Yorkshire, Latitude 53° 27′ 31″, in course of the Operations carried on for the Trigonometrical Survey of England, in the Years* 1800, 1801, *and* 1802. *By Major* William Mudge, *of the Royal Artillery, F. R. S.*

Read June 23, 1803.

SECTION FIRST.

In the last account presented to the Royal Society, I expressed my intentions of making the operations which were to follow that period, subservient to the purpose of measuring a portion of the meridional arc, running from Dunnose, in the Isle of Wight, into the northern part of Yorkshire. In the account referred to, (See Phil. Trans. for 1800, page 565,) I stated my reasons for adopting that resolution, and my hopes that Mr. Ramsden would shortly finish the zenith sector which his Grace the Duke of Richmond had bespoken of him, when Master General of the Ordnance. As that celebrated artist, from the beginning of the year 1800 till the middle of the following summer, had proceeded with little interruption, except from illness, towards its completion, the whole was brought so near to a conclusion before he died, that Mr. Berge found no difficulty in rendering it sufficiently perfect.

It is proper I should state, more fully than I have formerly

done, my reasons for selecting Dunnose as one of the extremities of my meridional line, and also those for preferring its meridian to any other; which I shall do as briefly as possible.

In a country whose surface, throughout its whole extent, is equally diversified with hilly ground, that particular part of it should be chosen, for carrying on a meridional measurement, which comprehends the most extensive arc. This arises from the necessary consequence which attends an operation in a country so circumstanced; as, possibly, no spot fixed on for a place of observation, could be supposed free from the effects of the unequal attraction in the adjoining matter. In such a country, therefore, a measurement upon the most extensive arc, must give the most accurate conclusion; for the errors arising from the cause here mentioned, like those of observation, lessen in their effects, on their application to arcs of increasing magnitude.

If Great Britain were a country thus diversified, the most eligible part would be that where the meridian from Lyme, in Dorsetshire, passes northward into Scotland. The difference of latitude between that place and Aberdeen, near to which that line cuts its parallel, is $4^{\circ}\ 47'$, nearly. But, however great the advantages attending such a length of arc might be, under the general circumstances of accurate terrestrial measurement, and accurate observations at its extremities, no beneficial consequences could be expected to attend the placing of the sector at intermediate stations; as the arc would be found running, almost every where, through a country abounding with hills, considerable both in magnitude and number.

Under this consideration, I determined to measure a portion of the meridian which proceeds from Dunnose to the mouth of the Tees; because, from inquiry, I had reason to suppose it the

longest meridional arc in Britain, free from any apparent obstruction. And I was led to select Dunnose for one of its extremities, as observations made there, in conjunction with others at Greenwich, would enable me to make corrections of the latitudes of places given in our former papers, if found necessary. By fixing on Dunnose, I had also the means of ascertaining the distance of the Royal Observatory from the northern or southern end of my line, and, consequently, of connecting it with the parallels of Dunkirk and Paris.

Dunnose being fixed on, my subsequent endeavours were directed towards carrying on the triangles, as nearly as I possibly could, in the direction of its meridian, selecting the stations so that their sides might be properly inclined to it, and of sufficient length. In choosing the station at the northern extremity, I was careful to select it as near the meridian of the southern one as possible, and likewise in the neighbourhood of some open spot of ground, proper for the measurement of a base of verification. A station having these advantages, was found near Clifton, a small village in the vicinity of Doncaster; and a level of sufficient extent for a base, on Misterton Carr, in the northern part of Lincolnshire.

In the composition of this account, I wish to confine myself to that part of my operations which relates merely to the matter expressed under its title. I am possessed of materials sufficient for another Paper; and shall give about thirteen hundred triangles, principal and secondary, when next I present an account of the Survey to the Society: professing this, I shall now say, that in 1800 and 1801, the angles of the triangles constituting the meridional series were observed; and that, in the latter year, the new base was measured on the abovementioned

Carr. I should not omit mentioning in this article, that while the instrument was at Clifton, the direction of the meridian was obtained from numerous observations on the pole star, at the times of its greatest eastern and western elongations from the meridian. It will be recollected, that similar observations were made at the station on Dunnose, in 1793; (see Phil. Trans. for 1795, page 460;) so that nothing relating to the terrestrial part of the operation remained to be performed at the expiration of 1801.

On my arrival in town, after the measurement of the base of verification in the north, I had the happiness of finding the zenith sector nearly completed. Little remained to be done, besides the dividing of its arch; an operation which Mr. BERGE proposed to defer till the following spring: it was then divided, and the instrument, being otherwise complete, was delivered into my hands in April. An observatory of convenient form having been previously made, the sector was immediately erected in the Tower; and, from thence, with the permission of Dr. MASKELYNE, it was sent to the Royal Observatory at Greenwich.

It is now necessary I should enter into a minute detail of this instrument's construction, giving a description of its several parts, with references to proper drawings. If, indeed, I had no other motives, I should perhaps be induced to do it from justice to the merit and memory of the ingenious inventor; who seems to have exerted his talents to the full extent of the hopes he entertained, of rendering this instrument the first of its kind.

General Description of the Zenith Sector.

In the sector I am going to describe, Mr. RAMSDEN has obviated the inconveniences attendant on the use of former sectors;

and has also diminished, in a very considerable degree, the errors unavoidably resulting from their imperfect construction. The principles on which he has founded the several improvements, consist in the means of uniting the sectorial tube to its axis, so as to ensure the permanency of the length of its radius, when erected for observation; more accurate methods of adjusting the instrument vertically; and an easy way of placing the face of its arch in the plane of the meridian. Another circumstance of moment was, some contrivance by which the plumb-line should be brought precisely over the point, marking the centre of the circle of which the divided arch of the sector should be a part. The last desideratum, the ingenious artist procured, by applying the same contrivance which so eminently displayed his skill, in the construction of the quadrant belonging to his Grace the Duke of MARLBOROUGH; a contrivance by which the plumb-line can be as readily adjusted over the required point, by a person standing on the ground, as any adjustment, or other act within his reach, can be performed. A description of this, as well as of the means by which the instrument is rendered vertical, and otherwise correctly prepared for observation, will be given, with the assistance of plates.

Plate IX. Exhibits a general view of the sector erected for observation: it consists of two parts; 1st, the frame which supports the apparatus to which the sectorial tube is attached; 2d, the work constituting that apparatus, with the tube itself.

The external frame or stand is made of mahogany, and unites strength with simplicity of construction. In shape, it is an obtruncated pyramid, whose base is a square of six feet in length, and whose vertex is half of it. This frame, although light in its make, is yet, when united by means of square-headed screws,

sufficiently firm. Inside this hollow stand is erected another frame, of the same substance, strong and well made, within which is suspended the sector; its frame being supported at top in every lateral direction, and sustained at bottom by a cone resting in a metallic concavity, the figure of which may be imagined, by supposing an arch of a circle to revolve round a tangent to one of its extremities. A cylinder, in the upper part of the interior stand, finds its place in an opening of an octagonal shape in the exterior frame, and, by a simple contrivance, is retained in that situation, while the sector and apparatus revolves on the cone. Thus, a ready means presents itself of turning the instrument round, with the face of its divided arch towards the east or west. It may be steadily retained in any position, by clamping it to the brass work of an azimuth circle, attached to the bottom of the external frame.

The direction of the meridian, at the place of observation, having been previously obtained from double azimuths of the pole star, this instrument admits of being placed in that direction very accurately. A telescope, twenty-nine inches in length, is attached to the side of the great tube, or rather, may be occasionally placed on a frame permanently fastened to it, having its axis in the plane of the divided arch, and very nearly at right angles to its radius. On the divided azimuth circle below, the angular bearing of any proper object may be set off, by turning the sector round till that object bisects the cross wires in the little telescope, and then noting the vernier. If the axis of the sector be horizontal, and the interior frame set perfectly upright, the instrument may be turned round from one point of the compass to the other, and properly adjusted for observation, in a few minutes.

In this general description, I am now to speak of one of the most ingenious contrivances attending the sector, which is, the means of readily adjusting the plumb-line in its several positions. I refer to the Plates and their descriptions, for a full account of it; but, as it will enable the reader to understand that which represents the instrument in its perspective view, (Plate IX.) I shall shortly describe this part.

The telescope of the sector is nearly eight feet long, and has an object-glass of four inches in diameter. It is attached to an axis, similar in shape to that of a transit-instrument, having at one end a lens, and near to the tube an arrangement of brass work, carrying a thin and diaphanous slice of mother-of-pearl, having, as appears to the naked eye, a dot upon it. The centre of this dot is by construction the true centre of the conical axis, and consequently of the circle of which the divided limb is a part. It is unnecessary to say, in this place, how that diaphragm was so adjusted as to have the centre of its dot where it should be, or the means by which it has been permanently fixed; it suffices that I say the point was placed most accurately, and the diaphragm fastened so firmly in the cone, that no readjustment of this part has been found necessary, since the sector came into my hands.

As the axis is hollow, a light, as that of a candle, held at its open end, is transmitted through the mother-of-pearl, which, stopping a part of its rays, exhibits a circle of red light to an eye looking through the lens at the opposite end of the axis; a well defined and exceedingly small dot appearing in the middle of the illuminated circle. Through proper openings in the upper and under parts of the axis, and suspended from a point not connected with it, passes the plumb-line, having its

position by construction *close to the dot*; so that, by looking through the axis in this way, the plumb-line appears like a small black line on the face of the mother-of-pearl.

Now it is evident that, to an eye thus placed, when the instrument is adjusted for observation, the plumb-line should appear as if accurately bisecting the dot. To give, therefore, the observer the means of moving it to the right or left, when standing on the ground, (avoiding thereby the inconvenient necessity of elevating himself on steps as high as the axis,) Mr. RAMSDEN placed a microscope, about 5 feet in length, parallel to the telescope, on the outside of the interior mahogany frame. This microscope, bent as it were at right angles at both ends, has one of them open, and placed close to the pivot of the axis carrying the small lens. In the upper part of the microscope, and just under its roof, is placed a speculum, inclined, at an angle of 45°, to the line passing through the centre of the sector's axis, and close to its end. This reflector receives the converged images of the dot and wire on the illuminated spectrum, and transmits them down the tube of the long microscope: the rays, falling on a *plano-convex* glass, at no great distance from the bottom, are finally sent out to the eye by a prismatic glass at the end of the tube. Thus viewed, that which to the naked eye above appeared a small dot on the illuminated lamina, when magnified, as delivered below, is seen to be a small and well defined circle with a luminous area, admitting of the most accurate means of deciding on the right position of the plumb-line, by exhibiting small portions of light between it and the periphery of the little circle.

The mode of illuminating the hollow axis is likewise ingenious. On the side of the interior mahogany frame, and opposite

to the vertical microscope, is suspended a lamp on two arches. At the back of it is a hollow cylindrical recess, in which is placed a polished metallic segment of a sphere. This concave reflector is attached to the cylinder, by means which give it any position required; so that the image of the burning wick, in the hollow of the lamp, may be thrown at pleasure on any spot above.

From the end of the conical axis, on the same side with this lamp, projects a small brass arm, carrying at its extremity a speculum, whose surface is placed at 45° with the vertical, and directly opposite the open end of the sector's axis. When the image of the burning wick is thrown from the concave reflector on the flat one above, the light passes through the hollow axis, illuminating the mother-of-pearl, and is, at last, sent down the microscopic tube to the eye below. This contrivance, collectively taken, is *unique*, and is full as accurate in its operation as ingenious in itself. From its nature, granting perfection of work, there can be no parallax between the dot and the wire. The images of the illuminated circle and wire, (plumb-line,) are coincident on the upper surface of the prismatic eye-glass, and transmitted so. In short, the whole has been so well managed, that the plumb-line can be made to bisect the dot or little circle, as accurately as the points on the divided limb of the sector. I consider this general description of this part of the instrument sufficient for the present; the proper plate, and its appropriate explanation, will supply what yet remains to be said.

The plumb-line is suspended above the upper part of the axis, from a point connected with the extremity of a bent lever, moveable round its fulcrum. The other end of the lever is acted on by a helical spring, which presses downwards, and causes

it to bear against a screw passing through a head of metal beneath that end. The extremity of the long screw is square, and has its place in a pipe attached to a mahogany rod, divided in the middle by a universal joint. One extremity of this rod is brought down, and received in a socket within convenient reach of the observer, who, looking at the image of the dot and wire, turns the rod, thus connected with the bent lever, and thereby gives motion to the plumb-line.

The pivots of the sector's axis are of bell metal, ground perfectly true and smooth. They rest in Ys, firmly attached to the upper part of the frame. The method of uniting the plates carrying those Ys, is as follows: at the upper part of the mahogany frame are four hollow strong cylinders of brass, which pass through the wooden work, and, at the same time, serve to connect very firmly the two sides of the upper part of the frame. These cylinders project about six inches beyond the surface of the wood, and have screws and nuts at their ends.

The brass plates furnished with the Ys, have four holes in each of them, which answer to the ends of the screws, and are attached to the cylinders furnished with those screws, by the respective nuts. In the Ys, the pivots of the axis are placed; and, as a means of adjusting each Y is fixed to each plate, any position, within a certain limit, may be assigned to the sector and its axis.

To prevent the pivots of the axis from moving to and fro in a sidelong direction, Mr. RAMSDEN adopted a contrivance for keeping them, at all times, in the same constant position in the Ys. This *desideratum* was not to be dispensed with; for, if the ends of the axis, from the thickening of the oil, or the accumulation of dust, should work laterally in their angles, the distance

between the plumb-line and arch would be continually varying; a perplexing evil, and the cause of great inaccuracy. The sum of this contrivance consists, first, in one of the Y plates having a small piece of brass screwed flat upon it, with a roller or friction-wheel at its end, which reaches just high enough to meet the vertical surface of the pivot a small distance within its circumference; and, secondly, in the other Y plate having a small apparatus, consisting of a lever furnished with another friction wheel and a spring, at its other extremity. This last mentioned roller, from the spring's action, presses against its proper pivot, and thrusts the other against the fixed wheel. By these simple but ingenious means, the axis is always retained in its proper situation with respect to the Ys.

To prevent the axis from bending, by the preponderance of the telescope and arches, Mr. RAMSDEN added braces and counterpoising weights. The braces are four in number, each being a hollow tube: they are fastened both to the axis and the telescope. Their principal uses consist in obviating the possibility of the telescope bending from accidental pressure, or vibrating when lightly touched. The method of preventing the telescope from sinking, or, in other words, the axis from bending, is by the use of levers and the abovementioned weights. These levers, two in number, are attached to the interior mahogany frame at top, the fulcrum of each being immoveable. At the end of each lever farthest from the tube, a weight is suspended, from a hook capable of being placed nearer to, or farther from, the fulcrum, at pleasure; thereby affording the means of raising the other end of the lever up against the cone, with any required degree of force. That extremity of the lever, so pressing upwards, has two large friction-wheels, which apply

themselves to the sides of the conical axis, but do not retard the free motion of it, when the telescope is moved in the direction of the plane of its arch. These wheels, two on each lever, support the axis near the junction of the telescopic tube; and, as a few ounces only are by these means suffered to press on the pivots, no bending takes place in the cones.

From the middle of the two uppermost horizontal cylinders, which unite the sides of the interior frame at top, and which receive, with the two beneath them, the respective Y plates, arises a small but substantial apparatus of metal, embracing a hollow brass cylinder, of five inches in diameter, and about three deep, which passes up into an opening in the upper part of the external mahogany frame. This cylinder, with its corresponding stand, are sustained, without any sort of shake, by a helical spring. This mode, with that of supporting the azimuth circle below, are so well managed, that when the instrument is properly adjusted for observation, the axis of the sector continues perfectly horizontal, in every position of the frame.

There is likewise a very convenient method of sustaining the sectorial tube in any required position for observation. Across the interior frame, about the height of the graduated arch, run two long brass axles, with two wheels on each, one precisely in the middle of the axle, (and consequently in the same plane with the line vertically cutting the middle of the telescope,) and the other close to the pinion at the end of the axle. From a steel pin, something peculiar in its construction, situated near the end of the telescope, proceeds a string, which is wound eight or ten turns round the pulley. Attached to the inside of the interior frame, and just above the wheels nearest to the end of the axle, is another pulley, over which, passing into a long and

narrow wooden compartment, is thrown a string, having a hook and a proper apparatus for receiving the moveable weights. The other end of this string is fastened to the pulley close to the axle, and gives motion to the telescope, or retains it in equilibrio, according to the arrangement of the two sets of weights, which consist of fifteen pieces of brass. By these means, all injurious pressure is taken off the point of the micrometer-screw, against which the telescope may be made to bear, with any required degree of force.

To cause the string passing over the middle of the pulley to draw in the exact direction of the limb's plane, Mr. RAMSDEN placed four small friction-wheels close to the eye end of the telescope, two on each side, and between each pair of wheels a steel pin, made like a T, with a hook at the end, to receive a string. This pin, where it applies to the wheels, is something in shape like a double cone, and is passed behind them. It always, from its construction, assumes the same position with regard to the friction-wheels; from which circumstance, the sustaining string is ever found in the plane passing through the centre of the telescope and the middle of the pulley.

The micrometer-screw, for measuring minutes and seconds, performs its operations in the usual way: it is moved backwards or forwards on a brass arch, parallel to the limb of the sector, and placed against the mahogany frame behind. To this arch the apparatus carrying the micrometer-screw is clamped; and it is adjusted, or brought parallel to the limb, by screws, so that the point of the micrometer-screw always bears exactly on the same part of the polished steel head, at the end of the sector.

The principal wires in the focus of the eye-glass are two, and are at right angles to each other. There are, indeed, two others

parallel to the meridional one, and at equal distances from it; they were placed there with a view of rendering an adjustment of the horizontal wire sufficiently easy. These are illuminated by means of the lamp which carries the concave reflector before spoken of. There is a hole, with a lens, in the side of the telescope, directly opposite to the lamp, having behind it a diaphragm of brass, coated with plaister of Paris, and inclined to the vertical axis of the tube, at an angle of 45 degrees. The quantity of light, suited to the circumstances of the observation, is regulated by coloured glasses, placed over the hole in the side of the tube.

The plummet, suspended at the wire, falls into a cylindrical cup, swinging by two pins on its edge, on the extremity of a brass frame annexed to the interior stand; which frame is capable of being raised or lowered at pleasure by a milled-headed screw; so that the wire can, at any time, be released from the weight of the plummet, by screwing up the vessel containing it.

There are two arches attached to the end of the tube, one on each side of it, and firmly united together by means of brass pillars; which arrangement effectually secures the divided arch from injury. The total extent of the arch is about 15°, having half of its subtense on each side zero. It is divided into every 5 minutes; the micrometer-screw measuring any supplementary quantity. Golden pins were let into the arch, by the advice of the Astronomer Royal, on which the divisions were laid off by Mr. BEIGE, in a very masterly and accurate manner, as will be seen hereafter. A magnifier, whose focal distance is about half an inch, is placed under the bottom of the cross piece opposite to the arch, and is furnished with a horizontal adjustment for bringing it directly over the plumb-line.

Among the various eye-pieces, of different magnifying powers, is one furnished with a prism. This, necessarily bent at right angles, enables the observer to see the stars without touching the frame. The use of it has been found convenient; but habit and proper caution enable the astronomer to use either of the other glasses. Having given this cursory and general description of the instrument, as seen at first view, I shall proceed to an explanation of the plates, which show its various parts.

Particular Description of the Zenith Sector.

Plate X. Represents a general section of the instrument and stand. AB is one of the four great uprights of the external mahogany frame, and CB its top, having an opening in D, for admission of light. The uprights consist of two strong pieces, firmly screwed together; each upright having seven strong screws, as seen in the upright AB. The top may be considered as a sort of square table, screwed down on the upper part of the frame. Between each of the two uprights is a brace, diagonally fixed, for strengthening the stand, as may be seen in the plate; and four others go horizontally, from upright to upright, for the purpose of still farther strengthening the whole. Across the bottom of the frame, and exactly in the middle of it, is a very strong mahogany plank, whereon rests the sector, having a stout straight edge bar of the same substance underneath. In the middle of this cross piece, as seen at E, is an apparatus of brass, furnished with an azimuth circle, having a hollow receptacle of bell-metal in the centre, in which rests, on a conical point, the interior mahogany frame FGHI. This brass work, which is strong and substantial, may be seen in Plate XIV. It is there represented *in plano*, with the bottom part of the interior stand

placed above it. The means of making the interior stand vertical, are found in the work annexed to the azimuth circle. They consist of two screws, attached to two plates of brass, placed at right angles to, and also flat on each other. S *s* (Plate XIV.) are the screws. A vernier on the divided circle may be seen at S; and at *s*, the method of clamping the bottom of the stand. On the opposite side is another provision for clamping this stand, when the face of the sector is changed from east to west, or *vice versâ*.

KLMNO *p* (Plate X.) is a section of the telescope and axis, MR, MR, being two of the four braces for strengthening the axis, and steadying the telescope. K is the place of the eye-tube; L the elliptical reflector for illuminating the wires at K; and ON a hollow cylinder of brass, independent of the tube. In the upper part of this cylinder, the object-glass is rivetted; the cylinder itself being fastened to the great eye-tube, in a permanent manner.

W, W, are two weights, hanging freely from the ends of two levers, the opposite ends being furnished with four friction-wheels. The points of support, between the weights and wheels, are at TT, being at the extremities of two upright solid pieces of metal, which are moved up or down by the screws beneath them. These counterpoising weights prevent any bending of the axis, between the pivots and those parts to which they apply. The apparatus for carrying the levers, is attached to the inside mahogany frame by screws, as represented in the section. See also Plate XIII.

The plummet and plumb-line are seen at *aed*; the point of suspension being *a*, and the plummet *d*; the plumb-line passing close by the arch, whose section is *bc*, and also near to the dot

or small circle *e*, described on the thin slice of mother-of-pearl, shown in the section of the axis at *e*.

A lamp is attached, or rather rests, on circular supports annexed to the side of the interior frame, and may be seen at XZ. At the back of the lamp, placed in a recess, is a concave reflector at Z; and, in the front of it, a tube running out to X, having a double convex glass at P, for throwing the light on L, which first passes through a double concave glass in the side of the telescope, and then, from the reflector L, is thrown down on the wires near K. The concave speculum Z, has two adjustments for converging the reflected light on the little elliptical speculum *b*. This last-mentioned speculum throws off the said light at *b*, which passes into the axis at G, illuminating the mother-of-pearl at *e*, and, finally, is transmitted out of the axis at *p*.

klmn, is a section of the long microscope, for conveying the image of the dot and wire, sent out of the axis at *p*, to the eye at *k*. This microscope is firmly attached to the side of the frame, by brass cylinders, *kk*, *ll*, *mm*, *n*, and has one plano-convex glass at *q*, a prismatic eye-glass at *u*, and a metallic reflector at the top, *o*. At the upper end of this long microscope, and directly behind the speculum, is a screw, by which the reflecting metal is brought into one of its requisite positions. The other adjustment of that metal is performed by two screws, which apply to the sides, and give it lateral motion. The plano-convex glass at *q*, is rivetted into the head of a long tube *uq*, which slides up the microscope. The upper part of the microscope at *o*, is placed exactly opposite the end of the axis, in a very firm way.

The rod for giving motion to the plumb-line, is *vwx*; *v* being the top of it, *w* the place of the universal joint, which separates the two parts of the rod, and *x* the bottom of the rod

itself, to which part the hand is applied. In this section, the top *v* is not furnished with the pipe connecting it with the bent lever above; but the representation of it, together with the lever itself, and accompanying spring, will be understood by referring to the plate which contains a representation of those parts.

In Plate XII. is a section of the axis passing through the pivots, and one exhibiting the face of the several united planes constituting the diaphragm, which adjust, in every direction, the slice of mother-of-pearl. Above this latter, is a view of the lever which gives motion to the plumb-line, with the pipe, spring, &c.; these are represented as seen from an eye at one of the pivots; and, above the other section, is a view of the same apparatus, seen in a direction at right angles to the former one.

In the latter of the above-mentioned sections, *bab* is the diaphragm, having in the middle, as at *p*, a circular piece of mother-of-pearl, extremely thin, with a small dot in the centre. This brass work is annexed to the large end of a hollow conical piece of brass, which exactly fits the axis at its proper place. It is there screwed fast, and may be considered as of one piece with the axis. In the adjoining figure, *bfkl*, is a section of the cone, *p* being the place in the opening of the brass work which receives the mother-of-pearl. In the representation of the diaphragm, *a* and *b* are two screws, at right angles to each other, and respectively attached to flat pieces of metal which slide on each other. If *fb* represent the plumb-line, the direction of each screw is that of an angle of 45 degrees with it. By means of these adjusting screws, the dot or little circle at *p* was placed in its proper position, or in the centre of the circle *abb*; so that, on an adjustment of the plumb-line, in any one position of the instrument, the dot still remains accurately bisected, however

the telescope be subsequently moved. Above *abb*, is a small frame-work of brass, from which the plumb-line depends: it is attached to two of the four horizontal tubes on which the Y frames are fastened. *cd* is the pipe fastened to the end of the rod; the end of this pipe has a screw, which passes through a nut, and acts against the end of the lever *d*, whose centre of motion is *g*, and whose other extremity is *f*, where there is a small piece of hard steel with a notch, for the reception of the plumb-line *fb*, suspended from *g*. Against the upper surface of the arm *gd*, a helical spring continually presses downwards; it is fastened above the end of the lever, at *e*; by which means, the arm *gd* is constantly pressed against the end of the pipe, obviating the possibility of any play or shake of the lever, round its centre *g*.

The same figure contains an elevation of the frame-work just described, as seen by an eye in the plane of the diaphragm produced. It is necessary that it should be closely inspected, for the purpose of obtaining an adequate idea of its construction. In this figure, *xv* is a small cylinder, with a screw and loose collar at the end *v*, for fastening the plumb-line, which goes over the notch *n*, and passes through a hole in the upper part of the axis at *f*, and out again at *b*, almost touching the mother-of-pearl at *p*. *sru* is a strong spring, fixed at *s*, through the middle of which, at *r*, passes a screw, which is, in fact, an adjusting screw, for bringing the plumb-line close to the dot on the surface of the diaphragm; and here it is necessary to observe, that the plane of the divided arch and that of this diaphragm, are one and the same when produced. There is no part of the instrument more complete than the apparatus for suspending the plumb-line, and that which regards the dot. I

shall now return to a farther consideration of the construction of the axis.

In Plate XII. there is also a horizontal view of the upper part of the axis; A being the head of the microscope, and B the little diagonal speculum, for throwing the light on the diaphragm. C is the opening in the axis above the object-glass; and D a brass slider, for covering the opening at C. E and F are two pulleys, attached to the side of the axis, over which pass two strings, having their ends united in opposite points of the shutter D; the other two ends of the string being within reach of the observer, who by this means easily opens or shuts the slider.

In Plate XIV. ABCD is the moveable frame, fastened to the top of the external stand, and having an octagonal opening at E, for receiving the brass work connected with the four horizontal pipes carrying the Ys. The touching points between the octagon and cylinder, are *g*, *b*, *n*, at which parts of the frame hard pieces of metal are inserted. To prevent all possibility of shake in the cylinder, which would render an adjustment of the instrument troublesome, if not impossible, there are two strong screws at *m* and *n*. One is a helix, which acts against *m*, and against the end of the sliding piece *n*; so that, by a condensation of the helix by the screw *m*, the piece *n* acts against the head of the cylinder inserted in E.

Plate XI. represents an elevation of the instrument seen sideways, and is that part to which the long microscope is attached: it serves to show the formation of the interior stand carrying the sectorial tube. A B C D E F are mahogany uprights, firmly united at the bottom and sides by proper cross pieces, and at top by the plate of metal *a b c d*, through the ends of which pass those of four horizontal pipes, the plate *a b c d* being one which

carries a Y, hidden in this elevation, by the upper part of the head of the microscope.

In the middle of the cross pieces, which unite the side of the frame to its corresponding one, are two wheels with long axles, as before mentioned. In this elevation they are seen at B and E; and have strings passing from them to their respective sides of the tube, where they attach to the pins P, P. At the ends of the axles nearest to this elevated side are two other pulleys. In the view which this plate affords, these wheels are projected against the others just spoken of; but their uses will be more readily understood, on perceiving the strings which pass over the upper pulleys, and afterwards sustain the weights W, W, in their upright cases.

In this elevation is seen the telescope attached to the side of the great tube: it is used when the instrument is got into the plane of the meridian. The vessel for receiving the plummet is seen at V; and at S the adjusting-screw, for elevating or depressing the frame which supports it. LL is the clamp-arch, supposed to be attached to the other side of the tube, or that which supports the lamp. At the bottom of the stand is seen the azimuth circle, and the apparatus belonging to it.

For the purpose of conveying a clear idea of the arrangement of the lower pulleys, and the manner in which the two arches are joined to each other at the end of the telescope, there is given, in Plate XII. a horizontal view of the same. The vessel for receiving the plummet, its supporting frame, and the magnifier for viewing the dots or points on the divided limb, are likewise represented. The body of the telescope is here taken away, leaving nothing more than the plate at its end, with the contiguous work belonging to the wires.

To show with distinctness and sufficient perspicuity, the manner in which the cross wires are sustained in the tube, also the means by which they are adjusted, figures are given in Plate XII. These also show the micrometer-screw, and the mode of clamping it to the proper arch. In the horizontal representation of the end of the telescope, the wires are seen in the centre, and also the two screws, with the helical spring for adjusting and retaining them. EF is a strong brass arch, with an edge bar IK, placed parallel to the divided arch. At EF are seen two milled-headed screws, passing through a metallic embracement of the bar and arch, which are firmly connected with the apparatus belonging to the micrometer by their means. At S is a piece of hard polished steel, against which the point of the micrometer-screw rests; and, as the arch EF is the segment of a circle whose radius is its distance from the axis of the sector, the point of that screw always buts against the steel head in the same place. In this plate is also seen a vertical section of the same parts. Here, EF is the back arch, and MS the micrometer-screw. This figure also shows the means by which the pieces carrying the wires, and inserted into the end of the telescope, are retained in their proper places. CA and DB are two long pillars, which pass through an annular piece of brass parallel to the end of the tube.

A screw with a windlas-like head is seen at G, from the turning of which, the wires are moved in one of their proper directions. A screw for giving them a motion at right angles to that obtained by the fore-mentioned one at G, is seen in the horizontal view of the end of the telescope at H.

It would be swelling this account to an inconvenient size, if I were to attempt any farther explanation of the plates; I shall,

therefore, close this article with a few observations on the manner of adjusting the instrument for observation.

Manner of adjusting the Instrument for Observation.

The feet of the external stand should be first carefully brought into a horizontal plane; and, when they are so, the azimuth circle will be, necessarily, parallel to it, having its centre under the middle of the opening in the mahogany frame screwed on the top of the stand. This being done, and the instrument set up, the plane of the arch should be brought parallel to one of the sides of the stand, in which situation, the internal frame is to be clamped to the azimuth circle, and the wire brought to its proper distance from the limb, by means of the adjusting-screw attached to one of the sliders, which carries the concave receptacle and conical point. The dot at zero should then be brought exactly under the plumb-line, as seen through the magnifier, and the point on the micrometer-head, at which its index stands, noted. The instrument is then to be turned half round; and, if the same dot on the arch still continues bisected, it will afford a proof of the internal stand being upright in one direction. But, if the dot should not continue bisected by the plumb-line, it must be made to do so, and the revolutions, or parts of a revolution, counted; half of which is to be turned back on the micrometer-head. The same dot, zero, is then to be brought under the wire, (plumb-line,) by means of the other adjusting-screw beneath the azimuth circle. If the stand is pretty accurately set up, one operation is sufficient for bringing the interior frame upright in one direction, *viz.* either in that of the meridian, or the one at right angles to it. The arch is then to be turned

round 90°, and the same operation gone through. This being properly done, the interior frame is made perfectly upright.

The next step to be taken, is that of placing the long level on its axis above, and rectifying that axis by means of the Y plate screws. If this be done carefully, the bubble will remain between the pointers of the level, whatever position the sector may be placed in. Having thus rectified the instrument, by making the internal frame upright, and the axis horizontal, the only remaining point to engage attention is, placing the plumb-line at a proper distance from the arch: this is done by means of the screw acting on the spring just under its point of suspension. If great care be used in going through these several adjustments, the instrument may, at any future time, be accurately adjusted for observation, by turning the proper screw belonging to the azimuth circle, and bringing the arch to its usual distance from the wire.

Laying off the Points, or dividing the Limb of the Sector.

The first step preparatory to finding the length of the radius, was to mount the sector in its frame, and adjust the counterpoising weights. By attention to the proper points on the levers, the axis was kept from bending, the pivots not having more than a weight of two pounds to support. This done, a tool with a well defined point was made to press lightly against the face of the arch, and firmly sustained in that situation, while the sectorial tube was slowly moved to the right and left: a fine line was by this means described on the limb, passing through the centres of the golden pins. The arch having been thus struck, the telescope was taken out of its frame, and laid on the

edge of a very strong plank, having its axis horizontal, and the pivots resting in Ys firmly fastened in the middle. The end of the arch, whose face became vertical, was supported by a brass plate screwed down on the end of the plank. When the pivots were placed in the Ys, and the telescope sustained in several places, to keep it from bending, a brass slider, on the surface of the plank, was moved till the line before mentioned coincided with that described on the arch. The telescope was then quickly taken out of the Ys, and, as speedily as possible, brought into a similar position on the other side; for which purpose, braces to support the tube had been previously prepared. By these means, twice the length of the radius was obtained; proper care having been taken to have the Ys so placed, that the centre of the pivots should be in the same plane with the two sliders at the extremities of the plank. The distance between the lines was then measured, and $\frac{1}{12}$ taken for the chord of 7° 10′, which was immediately laid off on the face of the sector, on both sides zero.

Although little doubt could be entertained of the truth of the total arc thus assumed, yet, that the length of its chord might be compared with that derived from the usual modes of operation, Mr. BERGE (as proposed by Mr. RAMSDEN) prepared a brass arch, which he let into a frame, on which, after striking a portion of a circle with the radius obtained as above, he laid off the chord of 60°. This arch he divided by continual bisection, till he obtained the chord of 7° 10′, which he compared with the same angle laid off on the sector's limb. He had the satisfaction of finding no perceivable difference; and, that there really existed none, was denoted by the unresisted fall of the points into their respective holes. The arch of the sector was then divided

into degrees, and every degree into five minutes; and the holes were afterwards opened with a tool made for the purpose. As gold pins had been let into the arch, Mr. BERGE was enabled to go through the division of it with great success, and afterwards to enlarge the holes, without destroying his accurate work. The observations will offer a more satisfactory testimony of the credit due to his abilities as a workman, than any opinion which I might express myself as entertaining, although founded on the same *data*. It remains for me only to observe, that I think he has delivered this instrument into my hands without any imperfection of execution; and that I believe it would not have been superior, had the ingenious inventor lived to complete it.

Adjustment of the meridional and horizontal Wires.

After the arch was divided, the axis of the telescope was laid on a pair of Ys connected to a firm support, and made nearly horizontal. The tube was then brought up to a level with the axis, and sustained at proper intervals, whilst the end of the telescope rested on a small piece of metal connected to a fixed bar, by means of an adjusting-screw. This end was then moved, till an object sufficiently small, (a speck or dot,) at a proper distance, appeared nearly in the centre of the field. The telescope was then properly secured from bending, and rendered perfectly steady, but admitting of a small motion sideways, the Ys having also a corresponding adjustment.

A microscope, furnished with a moveable wire, was then fastened to a beam attached to the brick wall, and its end brought close to the edge of the arch of the telescope. Upon this edge, as well as on that of the other arch, Mr. BERGE had the address to lay off a point, very nearly in that place where the

plane passing through the axis and zero cuts the arches. This being done, the telescope and Ys were moved laterally, till the vertical wire bisected the speck. The system of wires was then turned, till the meridional one was made exactly perpendicular to the axis, as seen from the mark being bisected in every part of the wire, when the end of the telescope was moved up and down by the adjusting-screw. The axis was then carefully taken out of the Ys, and inverted: it was afterwards placed as before, and the distance between the spot and vertical wire estimated by the eye. The telescope was then moved in azimuth, half that quantity, and the meridional wire brought to a bisection on the speck. Repeating this operation twice or thrice, the vertical wire became accurately perpendicular to the line passing through the centre of the conical axis, and also in the plane passing through the centre of the tube.

The next step was, to move the whole system of wires in the direction of the perpendicular, in order that the horizontal one (at right angles to the vertical wire by construction) should be also brought into its proper position. For this purpose, the telescope was moved a little in azimuth, and the proper wire made to bisect it accurately, at which time, the wire of the micrometer before mentioned was brought over the dot on the edge of the limb.

In this position of things, the instrument was taken off the Ys, and turned over; it was then again carefully placed in its former position, and the end of the telescope brought up by the adjusting-screw, till the distant speck was bisected by the horizontal wire. Now, if this horizontal wire had been, by accident, placed so that the point of intersection of the two wires was

exactly in the true centre of the telescope, the dot on the edge of the other limb would have been bisected by the wire of the anterior microscope. This was found not to be the case; but it was made to be so, by halving the differences, and moving the horizontal wire so as to bisect the mark. After this had been again examined, the vertical wire was examined, when it was found necessary to go through a part of the operation a second time. This was to be expected; but the wires were, by these means, at last properly placed, and guards were then fixed over their adjusting-screws. I shall now proceed to speak of the use I made of this sector in the year 1802.

Particulars relating to the Operations of the Year 1802.

I have already stated, that a proper observatory had been provided for the reception of the zenith sector. The dimensions of it were twelve feet square at bottom, and six feet square at top; its proportions being the same as those of the external stand. A floor having a square vacuity, to admit of the instrument standing on the ground, covered the joists of it. The sides of the observatory were of strong painted canvas; and the roof of wood, with an aperture, which could be opened or closed at pleasure, for viewing the stars near the zenith.

The instrument, with this observatory, was erected in the Tower on the 3d of April, merely to examine all its parts, and to ascertain whether any thing could be done to render it more perfect. Some trifling *addenda* were accordingly made, and the whole, thus rendered perfect, was removed to the Royal Observatory, and erected in the garden of the Astronomer Royal, close to the eastern extremity of the transit room.

I am now to specify, that my intentions were to devote, from this period, the whole or the greatest part of the following summer, to the use of this sector; nor did I indeed imagine such a portion of time more than sufficient. I purposed to erect it at Dunnose, and at Clifton, the extremities of my arc; and also at Arbury Hill, near Daventry, the station almost in the middle of it. This last station I fixed upon, because it was proper to ascertain how far the observations for determining the extent of the whole arc, would agree with any others made for finding the value of its parts. The erecting of it at Greenwich was necessary, for the purpose of observing the zenith distances of certain stars, which were afterwards to be observed at Dunnose, thereby affording means of ascertaining the latitude of that station.

The instrument remained at the Royal Observatory till the 26th of April; and, although the weather was for most part of the time unfavourable, yet the erecting of it there will be found, as appears in a future part of this work, to have answered the proposed end. One very material service accrued to myself; this was, the advice and instruction I received from the Astronomer Royal, for the successful management of the sector, by which I scrupulously governed myself throughout the whole of the subsequent campaign. Having observed the zenith distances of some few stars, and made myself completely master of every adjustment about the instrument, the sector, with all its apparatus, was sent to the Isle of Wight, by way of Southampton; every possible care being used to protect it from injury, not only while transporting by land, but also when under the act of being taken into, and removed out of, the vessel which conveyed

it from that place to Cowes. It will be readily supposed, that watchfulness and care were necessary, to preserve this complicated instrument from being damaged by accident or roughness of the roads.

In the year 1794, an iron cannon was sunk in the ground, for the purpose of permanently preserving the point on Dunnose, where the direction of the meridian was observed in 1793. It must be now remarked, that the cannon so inserted could not have its breech placed so low as might have been wished; in consequence of which, it became necessary to erect the observatory for the reception of the sector some little distance southward of the old station. The distance from the centre of the gun to the point over which the instrument was afterwards erected, was six feet and a half.

To procure for the external stand, and thence for the whole apparatus, a firm foundation, I caused four long stakes to be driven into the ground, one for each foot of the stand, to which its feet were firmly screwed down. The surfaces of the stakes were then cut off smooth, and brought into the same horizontal plane, by which means, the interior frame and sector were placed much within the limits of their several adjustments.

The pointed top of Sir RICHARD WORSLEY'S obelisk afforded me an excellent means for bringing, with the assistance of the side telescope and azimuth circle, the plane of the arch into the true meridian. The distance and magnitude of that object is extremely convenient for the purpose. Its bearing from the meridian of the station is 87° 42′ 33″, as I shall show in its proper place. The side telescope was turned to this object very frequently; and I never found the vernier, on the azimuth circle,

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to indicate any serious warp in the stand. Its greatest variation was 4′; but, for several days together, it did not amount to 30″.

The weight of the plummet, I adjusted to the strength of the plumb-line, in the usual way. I suspended it in air, and gradually increased its weight, till the wire broke. This plummet was then immersed in the vessel appropriated for its reception. It will, perhaps, not be improper to observe, that I was careful to give the plummet its maximum of weight, that its wire might not be subject to motion from streams of air.

As it was to be apprehended that errors would result, from the effects of an inequality of temperature in the air within the observatory, I placed two thermometers, both adjusted to a third, near the telescope. One I elevated as high as the axis, the other I laid on the hollow brass cylinders which connect the divided arch with that behind it, usually called the back arch. In the day, I found (as may be seen in the register of observations) the heat a little greater at the top of the tent than towards the bottom; and the reverse was generally the case at night.

To equalize the temperature at those times when the sun shone out, or the weather was hot, I opened the shutters in the roof, as well as the door of the observatory, a considerable time before the moment of observation. By these means, the air within the tent was rendered tolerably uniform in its degrees of heat. For the space of a week following the commencement of my observations, I suspended a third thermometer from the milled-headed key which turns the diaphragm placed inside the telescope. As the situation of this thermometer was midway between the two others just mentioned, I always found the temperature there, a mean between those degrees shown by the

upper and under thermometers; and as, in the course of the time specified, I had various opportunities of satisfying myself on this point, I desisted from making any farther use of it. For the purpose of ascertaining the limits of the errors likely to result from the cause now spoken of, it will be right to institute some little inquiry into its mode of operation.

In Plate XVI. Fig. 1, let CD be the line passing through the centre of the sectorial tube, brought into any position for observation; the angle made with the zenith being ACB, and CA the consequent direction of the plumb-line. CB and BA may therefore represent the radius and arch of the sector, when in a state of uniform temperature throughout.

Now, at any time, let the thermometer at the top C, indicate a degree of heat superior to that shewn by the other at B; and let it also be supposed, that the difference between those degrees of heat, at any intermediate point, is directly as the distance of that point from C or B; and farther, let the tube CB be extended to D, while the arch AB continues of the same length.

If the line CA be extended to F, and the line AE be drawn parallel to BD, meeting the arch FD in E, then will the small space FE measure the error in the observed zenith distance of the star.

As the angle ACB must in all cases be small, ACB and EF may be considered as two similar sectors of circles; under which supposition, we get $FE = \frac{AB \cdot EA}{CB}$; and, applying this to an extreme case occurring at Arbury Hill, on the 19th of September, we get $AE = \frac{5^{\circ} \times 0{,}0001237 \text{ inches} \times CB}{2 \times 12}$, hence $FE = \frac{5^{\circ} \times 0{,}0001237 \times 6^{\text{h}}.28'}{2 \times 12}$ $= 0''{,}396$.

As few of the stars selected for observation were, at either of

the stations, so far from the zenith as 6°, it is obvious little inaccuracy can have resulted from the difference of temperature here spoken of; and this supposition will receive farther support, from the actually near approach of the two temperatures to an equality with each other, as appears by taking the mean results of the last two columns in the register of observations. That the scrupulous mind may be satisfied in this particular, I shall insert, in its proper place, a table for supplying the correction arising from this cause; as the effect of a greater heat in the upper part of the tent is an error in excess, so a reverse of the case produces one in defect.

On the first convenient opportunity, I measured, with great care, the distances between every successive set of dots on the divided arch, contained between zero and 7° 10′. This was done at a time when the thermometers denoted a perfect uniformity in the temperature of the air within the tent, and when, from the calmness of the day, no streams of air could affect the plumb-line. Although I had, previously to the performance of this matter, perfectly satisfied myself that the rays of heat, emitted from the lamp illuminating the face of the arch, do not expand it perceivably, yet I thought it best to wait for a day when the strength of the light should enable me to discover, and properly bisect, the points, without the aid of that lamp. Between zero and 7° 10′, on the left hand arch, I found there were 430 revolutions of the micrometer-screw + 38,2 divisions; and, between the same point and 7° 10′ on the right hand, 430 revolutions + 39,2 divisions.

From this it appears, that the mean value of one revolution of the screw, is 0′ 59″,098. Mr. BERGE endeavoured to place the arch, carrying the apparatus of the micrometer, so that one revolution

of the screw should be exactly a minute. On trial, he found it nearly a second short; for which reason, he divided the head into 59 parts, and called each of them a second. I think it proper to repeat the observation, that the two arches were measured with the greatest care, because it admits of the remark, that every space subtending 5′ was measured with the *same part* of the screw, beginning very nearly from 9 on the index. This instrument will, at a future period, probably pass into other hands; it may therefore be right to state, that I found, from an examination of the screw, an error of nearly 1″, in the part contained between 17 and 19 on the index, arising from a small notch which, with a magnifier, I could plainly perceive on one of the threads. As it cannot but be the general wish to have some evidence of the accuracy with which this sector has been divided, and also how far I have succeeded in the performance of what is now under consideration, a table will be given, in which the value of every 5′, in the first degree on each side zero, will be found in revolutions and parts of the screw.

Having towards the end of June found my observations sufficiently numerous, and apparently sufficiently accurate, from the regular differences subsisting amongst them, I took down the sector, and, with every thing belonging to it, repaired to Clifton, the northern extremity of my arch. The instrument arrived there in safety, on the 20th of July; and, as the direction of the meridian had been previously determined, the instrument was immediately set up, and made ready for use.

At this station, Laughton spire afforded me an excellent mark for adjusting the instrument in the plane of the meridian. The bearing of it is 1° 56′ 12″ south-west; and, from my being able to see it in the observatory, without rolling up either of its

canvas sides, I had ready means, at all times, of turning the telescope to that object. And I can take upon me to say, that during the whole of my stay at this station, I never found the instrument out of the plane of the meridian more than half a minute.

Of the 27 stars observed at Dunnose, 17 were observed at this station; they were the following, *viz.* β, γ, 45*d*, 46*c*, 51, 16, μ, Draconis; 1κ, 10ν, Cygni; η, ξ, Ursæ; 22τ, 85ν, 52, υ, Herculis; α Persei, and Capella.

As the weather for most part of the time proved favourable, the observations were completed on the 22d of July; and, as there appeared to be sufficient time, between that period and the arrival of the season which would necessarily terminate my operations, to carry on my meridional line to the Tees mouth, I reconnoitered the country in that quarter, and selected the stations all the way between it and Clifton.

On the 23d of July, the instrument and observatory were taken down, and the large theodolite erected over the point. White lights were sent to the distant stations, and were all observed, except those fired on the 30th day of the same month; and, as the night on which those lights were burnt was remarkably clear, and it was therefore probable that some intervening land obscured the distant hill, I desisted from making any farther attempt towards the execution of the above scheme, as any greater loss of time might prevent me from making the proposed observations on Arbury Hill. I therefore sent the sector to this last-mentioned place, where it arrived on the 3d of September, and was erected on the 7th, the direction of the meridian having been previously ascertained, by two double azimuths of the pole star. But it is proper I should observe,

that the sector was not set up over the old station, as injury to some amount would have been sustained by the person farming the soil, owing to its cultivated state. The spot on which I fixed, was 34 feet to the north, and 28 towards the west, of the former station.

Of the stars seen at Clifton, 12 were observed at Arbury Hill. These observations were continued, with very little interruption, till the 4th of October, when the party, with all the apparatus, returned to London; the zenith sector being found as perfect on its return as when first sent into the field, a circumstance inferring both the strength and perfect union of its parts.

Particulars relating to the Measurement of a new Base Line, on Misterton Carr, in the Year 1801.

The apparatus used for the measurement of this base, was the same as that employed on Hounslow Heath, Salisbury Plain, and Sedgemoor; and the like pains were taken to ensure its accuracy, as were used on those occasions. The points for lining out the base were put into the ground with great truth and precision; the large theodolite being used as one of the means, and in the same way as in measuring the base on Salisbury plain. Previous to the commencement of this operation, two large blocks of oak, with square holes on their upper surfaces, were sunk in the ground, at the extremities of the base; the point of intersection of the diagonals of each hole, severally denoting them. These diagonals were drawn on lead, cast into the holes, and ground to a smooth plane, even with the surface of the block.

Before the measurement began, the working chain A, and the

50-feet chain, were both compared with the standard B. For this purpose, a calm cloudy day was waited for, which opportunity presented itself on the 2d of June. The pickets for the registered heads were then driven into the ground a considerable depth, and the coffers laid in a right line between them. The chain A was then laid out perfectly straight; and five thermometers, equally distant from each other, were put close to its side, their temperatures being as follows.

Thermometers.

1	2	3	4	5
67°	65°	67°,5	67°,5	67°,5

The chain A was then taken out of the coffers, and B laid out in its stead. The difference of their lengths, which was measured with the micrometer-screw, was found to be 1 revolution 6 divisions, *viz.* A longer than B; the temperature remaining constant the whole time of trial. In the course of the day, the same operation was repeated, the five thermometers standing at 69°,5—69°—69°,5—69°—69°, when B was found to be 1 revolution $6\frac{1}{2}$ divisions of the micrometer-head shorter than A. Therefore, the mean, *viz.* 1 revolution $6\frac{1}{4}$ divisions, was considered as the true difference of their lengths. The length of twice the 50-feet chain was, at this trial, found to exceed that of B, 2 revolutions 4,5 divisions; which is nearly the same determination as formerly resulted, from a comparison of the chains with each other on Sedgemoor. It may be seen too, by referring to the account of the measurement of the base on that spot, that the difference between the lengths of the standard B and common chain A, was nearly the same at that period as now; the difference being 1 revolution 7 divisions. I therefore concluded I might,

with safety, suppose the length of the standard chain B to be exactly the same then, as at the period when Mr. RAMSDEN compared it with the points inserted into the cast iron bar, mentioned in the first account of the trigonometrical operations.

The measurement of this, the fourth base, commenced on the 6th of June; and was continued, without much interruption from bad weather or other causes, till the 28th of July, when it concluded with the 263d chain, the overplus, 38,321 feet, being carefully determined, by means of a silver wire and pointed plummet let fall over the point marking the north-west extremity of the base. The two chains were then carefully compared with each other; when it was found, that the wear of the chain A was exactly one division on the micrometer-head, or $\frac{1}{250}$ part of an inch. As the length of this base is nearly the same as that on Sedgemoor, it was reasonable to suppose that the elongation of the chain, by the working of the joints in each measurement, would be found the same, provided no injury had taken place from accidental circumstances, or rusting of the pivots and holes, during the time the chains were laid up in the Tower. After the reduction of the base, I shall have occasion to show that my ideas were correct in this point, as Mr. BERGE has lately remeasured both chains.

Angles of the great Triangles observed in the Years 1800, 1801.

At Beacon Hill.

Between	°	′	″	Mean.
The north and south end of base -	20	47	19	″
			20	19,75
			20,25	

Between		°	′	″	Mean.
North end of Base and Gringley	-	34	44	40,75 42,25 42,75 43,25	″ 42,25
Gringley and south end of Base	-	18	57	22,75 24 24,25 25	24
Heathersedge and Gringley	-	138	9	15,5 16 17,5	16
At North End of Base.					
Beacon Hill and south end of Base	-	60	17	16 16,25 17,25	16,5
Beacon Hill and Gringley	-	74	46	55,5 56,25 57,25 58	56,5
At South End of Base.					
Beacon Hill and north end of Base	-	98	55	26 27 28 29	27,5
Beacon Hill and Gringley	-	114	51	31,5 31,75 32,5 32,75 33,75	32,5
At Gringley.					
Beacon Hill and south end of base	-	51	11	5,25 5,75 6,75 7,25 7,5	6,5

Between	°	′	″	Mean.
Beacon Hill and north end of Base -	70	28	21,5	
			21,75	22,25
			22,5	
			23,25	
Beacon Hill and Heathersedge -	23	10	5	
			6	6
			7	
Sutton Ashfield and Heathersedge -	46	20	23,5	
			24,5	24

At Heathersedge.

Beacon Hill and Gringley - -	80	40	37,75	
			38,5	38,5
			39,25	
Sutton Ashfield and Gringley -	54	52	36,5	
			37,5	37,5
			38,5	
Orpit and Sutton Ashfield - -	39	8	37,25	
			37,75	
			38,25	38,75
			39,5	
			39,75	

At Sutton Ashfield.

Heathersedge and Gringley - -	78	47	1,25	
			2,25	2
			2,5	
Orpit and Heathersedge - -	60	22	24,5	
			25,5	25,5
			26,5	
Hollan Hill and Orpit - -	113	49	8	
			9	9
			10	

At Orpit.

Between	°	′	″	Mean.
Heathersedge and Sutton Ashfield -	80	28	56,25	
			56,75	″
			57,75	57,25
			58,25	
Hollan Hill and Sutton Ashfield -	21	27	19,5	
			20	
			20,5	20,5
			21	
			21,75	
Bardon Hill and Hollan Hill - -	62	8	24,5	
			25	25
			25,5	
Castle Ring and Bardon Hill -	56	8	13,75	
			14,75	14,75
			15,75	

At Hollan Hill.

Sutton Ashfield and Orpit - -	44	48	30,75	
			32,5	32
			32,75	
Bardon Hill and Orpit - -	74	52	36,25	
			37,75	
			38,75	38
			39,25	

At Bardon Hill.

Hollan Hill and Orpit - - -	42	58	58,75	
			59,25	
			59,75	59,5
			60,25	
Castle Ring and Orpit - -	68	24	3,75	
			4,75	4,75
			5,75	
Corley and Arbury Hill - -	38	25	12,5	
			13,25	13,25
			14,25	

At Castle Ring.

Between	°	′	″	Mean.
Bardon Hill and Orpit - - -	55	32	43	
			43,25	
			43,75	″
			44,25	44
			44,75	
			45	
Corley and Bardon Hill - -	47	54	40,5	
			41,75	
			42,5	42,25
			43,25	
			43,5	

At Corley.

Castle Ring and Bardon Hill - -	72	32	45,75	
			46,25	
			46,75	46,5
			47	
Arbury Hill and Bardon Hill -	107	20	13,5	
			14,25	14,25
			15,75	

At Arbury Hill.

Corley and Bardon Hill - -	84	14	32,5	
			33,25	33,5*
			34,25	

Reduction of the Base to the Temperature of 62°.

The apparent length of the base was 259 chains of 100 feet each, + 8 chains of 50 feet each, and the overplus of the last chain *viz.* 38,321 feet - Feet. 26398,321

The chain B, before the measurement, was found to be 16¼ divisions on the micrometer-head shorter

* For the observations of the angles of the triangles southward of Arbury Hill, see the Philosophical Transactions for 1795 and 1800.

than A, the length of which, according to Mr. RAMSDEN's determination, may be taken = 100 feet + 0,1236 inches, in the temperature of 54°; which gives A 0,12363 parts of an inch too long. Therefore, if to this is added half the wear, *viz.* 0,00192 parts of an inch, we shall get $\frac{0.12555}{12}$, which × 259 gives 2,709 feet, which add - - - - + 2,709

The 50-feet chain, before the measurement, was compared also with B, and found to be 24 divisions on the micrometer-head longer; therefore, $\frac{0.0943}{12} \times 4$ = 0,0314 parts of a foot, which likewise add - + 0,031

Again, the sum of all the degrees shown on the thermometers was 98083, wherefore, $\frac{98083}{5} - 54° \times 263,38 \times \frac{0.0075}{12}$ = 3,3713 feet, is the correction for the mean heat in which the base was measured above 54°, the temperature in which the chains were laid off, and this also add - - - - + 3,371

Finally, for the reduction to the temperature of 62°, or 8° on the brass scale, we have $\frac{0.1237 \times 263.38 \times 8°}{12}$ = 1,720 feet, which subtract - - - — 1,720

Hence we have the true length of the base, in the temperature of 62°, = - - - 26342,712

The surface of the ground on which this base was horizontally measured, is said to be not more than 85 feet above the surface of the sea, in the mouth of the Humber, at *half tide*. And, although it may not perhaps be a very correct deduction, yet, as I understand that conclusion arose out of a levelling operation, it may be taken for granted that we shall not err, as

to sense, in our conclusions, if we consider Misterton Carr as situated on the mean surface of the spheroid. I shall, therefore, take 26342,7 feet for the true length of the base; and I think it cannot exceed or fall short of that quantity, more than two inches.

Recent Comparisons of the standard and working Chains, with the points inserted in the cast Iron Bar.

In the reduction of the foregoing base, I have taken it for granted, that the standard chain is precisely of the same length as when it first came out of the hands of Mr. Ramsden. Circumstances which need not be mentioned in this part of my paper, but which, in their proper places, will be explained, have induced me to get both the long chains remeasured. Mr. Berge, therefore, at my request, prepared the bar and plank, and lately went through the required operation. The particulars were as follow.

The chain B was first measured in five successive removes, the first space of 20 feet having a thermometer in the middle of the bar, which stood at 48°; the second space or remove, having the same thermometer at 48°,2; the third, at 48°,5; the fourth, at 48°,8; and the 5th, at 48°,8; which gave the total length of the chain = 100 feet + 0,077 parts of an inch, in the mean temperature of 48°,6.

The standard A was then measured in five successive removes; the thermometer at each remove being 48°,5 — 48°,6 — 48°,7 — 48°,8 — 48°,8; which gave the length of A = 100 feet + 0,132 parts of an inch, in the temperature 48,°7.

From the Table of expansions in Vol. LXXV. of the Phil. Trans. the difference between the expansion of a rod of steel

and one of cast iron, both of ten feet in length, is found to be 0,00001 part of an inch; therefore, the length of the chains, in the temperature of 54°, agreeing with the points on the bar, will be A = 100 feet + 0,1825 inches.

B = 100 feet + 0,0778 inches.

In the Phil. Trans. for 1795, page 437, their lengths, in the same temperature, as deduced by Mr. RAMSDEN, are stated to be A = 100 feet + 0,11425 inches.

B = 100 feet + 0,05825 inches; which gives a difference something less than $\frac{3}{100}$ of inch between their present and former lengths.

In the reduction of the preceding base, I have supposed the working chain A to be 0,12363 parts of an inch too long before the measurement began. If to this the whole wear be added, *viz.* 0,00384, we shall have the length of it, 100 feet + 0,1275 parts of an inch; which differs only $\frac{3}{1000}$ from the late determination of Mr. BERGE.

Calculation of the Sides of a Series of Triangles, extending from Dunnose, in the Isle of Wight, to Clifton, in Yorkshire. Plate XV.

In the former accounts of the trigonometrical operations it will be found, that triangles have been carried on from Dunnose to Arbury Hill. It will be proper to give them in this place, that the series may be complete, thereby superceding the necessity of frequently referring to those papers.

Butser Hill from Dunnose, 140580,4 feet. Phil. Trans. for 1795, p. 501.

No. of triangles.	Names of stations.	Observed angles.	Diff.	Spherical excess.	Error.	Angles corrected for calculation.	Distances.
		° ′ ″	″	″	″	° ′ ″	Feet.
I.	Butser Hill	76 12 22	−1,99			76 12 21,5	
	Dean Hill	48 4 32,25	−1,54			48 4 31,75	
	Dunnose	55 43 7	−1,53			55 43 6,75	
		180 0 1,25		5,0	−3,75		
	Dunnose from { Butser Hill						140580,4
	Dunnose from { Dean Hill						183496,2
II.	Dean Hill	62 22 48,75	−1,37			62 22 47	
	Butser Hill	48 28 41,5	−1,23			48 28 40	
	Highclere	69 8 35	−1,5			69 8 33	
		180 0 5,25		4,07	+1,18		
	Dean Hill from { Butser Hill						156122,1
	Dean Hill from { Highclere						125084,9
III.	Butser Hill	84 31 45,5	−1,2			84 31 44,5	
	Hind Head	66 15 54,5	−0,83			66 15 54,25	
	Highclere	29 12 22	−0,72			29 12 21,25	
		180 0 2		2,7	−0,7		
	Butser Hill from { Hind Head						78905,7
	Butser Hill from { Highclere						148031,0
IV.	Highclere	34 46 15,75	−0,81			34 46 15	
	Hind Head	83 20 14,25	−1,36			83 20 14	
	Bagshot Heath	34 46 15,75	−1,88			61 53 31	
		180 0 1,75		3,09	−1,34		
	Highclere from { Bagshot Heath						142952,6
	Highclere from { Hind Head						160972,2

No. of triangles.	Names of stations.	Observed angles.	Diff.	Spherical excess.	Error.	Angles corrected for calculation.	Distances.
		° ′ ″	″	″	″	° ′ ″	Feet.
V.	Bagshot Heath	55 32 26	—0,89			55 32 25,25	
	Highclere	40 10 18,25	—0,83			40 10 17,75	
	Nuffield	78 17 18,25	—1,20			78 17 17	
		180 0 2,5		2,94	—0,43		
	Nuffield from { Bagshot Heath						105321,2
	Nuffield from { Highclere						120374
VI.	White Horse Hill	63 7 53,25	—0,94			63 7 53,5	
	Highclere	63 18 16,75	—0,94			63 18 17	
	Nuffield	53 33 49,5	—0,86			53 33 49,5	
		179 59 59,5		2,74	—3,24		
	White Horse Hill from { Nuffield						120557,7
	White Horse Hill from { Highclere						108503,1
VII.	White Horse Hill	38 48 13,25	—0,67			38 48 12,5	
	Nuffield	86 4 16,25	—1,21			86 4 15	
	Brill	55 7 33,5	—0,71			55 7 32,5	
		186 0 3		2,6	+0,4		
	Brill from { White Horse Hill						146603,2
	Brill from { Nuffield						92805,5
VIII.	Brill	50 14 44,5	—1,18			50 14 45	
	White Horse Hill	64 45 43,75	—1,34			64 45 42,5	
	Stow on the Wold	64 59 32	—1,35			64 59 32,5	
		180 0 0,25		3,88	—3,63		
	Stow from { White Horse Hill						124365,6
	Stow from { Brill						140320,3
IX.	Brill	32 34 43	—0,61			32 34 42,25	
	Stow on the Wold	60 56 0,25	—0,64			60 56 5,5	
	Epwell	86 29 13,25	—0,11			86 29 12,25	
		180 0 2,75		2,37	+0,38		
	Epwell from { Stow						78938,2
	Epwell from { Brill						128140

No. of triangles.	Names of stations.	Observed angles.	Diff.	Spherical excess.	Error.	Angles corrected for calculation.	Distances.
		° ′ ″	″	″	″	° ′ ″	Feet.
x.	Brill - -	34 23 58,5	−0,65			34 23 57,5	
	Epwell - -	85 0 18,5	−1,10			85 0 17,5	
	Arbury Hill -	60 35 45,5	−0,70			60 35 45	
		180 0 22,5		2,46	+0,04		
	Arbury Hill from { Epwell - - -						83098,4
	Arbury Hill from { Brill - - - -						140530
xi.	Arbury Hill -	89 57 4,5	−1,14			89 57 5,5	
	Epwell - -	54 45 18,75	−0,57			54 45 18,25	
	Corley - -	35 17 36,75	−0,57			35 17 36,25	
		180 0 0		2,29	−2,29		
	Corley from - { Arbury Hill - -						117463
	Corley from - { Epwell - - -						143827,8

By the last triangle, the distance from Corley to Arbury Hill is 117463 feet, which distance, and all the others constituting the sides of this part of the series, are deduced from the base on Hounslow Heath, as well as that on Salisbury Plain. With regard to the triangles connecting the stations at Corley and Arbury Hill with the base recently measured in the north, it will be proper to let them rest partly on that base, and partly on the side Corley and Arbury Hill. And here I would remark, that in carrying on a series of triangles, whether for the purpose of a meridional measurement or otherwise, it is proper that a base of verification, answering at the same time as a new one of departure, should be measured every hundred miles at least. With this idea, therefore, the foregoing triangles, as well as those composing the remaining part of the series, should be furnished with three base lines, *viz.* one at each extremity, and the other in the middle. In calculating the sides, were the series thus

circumstanced, it would be right to depend on each base for one third of the distance between it and the one next at hand, and use the mean result, as derived from the two adjoining bases, for the true lengths of the several sides within the other third. Thus, if two bases were found at the extremities of the arc in question, and one in the middle, as about Brill, the computation should be carried on, from the extreme bases, about one-sixth part of the meridional distance; and, from the middle base, one-third of the intermediate distance on each side; the remaining two arcs being determined from the respective base lines. That I may avoid prolixity, or the appearance of it, I shall compute the sides of the triangles northward of the two stations before mentioned, from the base measured on Misterton Carr only, and use the mean distances calculated on the above principle, when I find the total length of my arc.

Length of the Base on Misterton Carr, 26342,7 Feet.

No. of triangles.	Names of stations.	Observed angles.	Diff.	Spherical excess.	Error.	Angles corrected for calculation.	Distances.
		° ′ ″	″	″	″	° ′ ″	Feet.
XII.	Beacon Hill -	20 47 19,75				20 47 20	
	North end of Base	60 17 16,5				60 17 13	
	South end of Base	98 55 27,5				98 55 27	
		180 0 3,75					
	Beacon Hill from { North end of Base -						64461,7
	{ South end of Base -						73321,9
XIII.	Beacon Hill -	34 44 42,75				34 44 42	
	North end of Base	74 46 56,5				74 46 56	
	Gringley on the Hill	70 28 22,25				70 28 22	
		180 9 1					
	Gringley from { North end of Base -						44338,2
	{ Beacon Hill -						75068,0

No. of triangles.	Names of stations.	Observed angles.	Diff.	Spherical excess.	Error.	Angles corrected for calculation.	Distances.
		° ′ ″	″	″	″	° ′ ″	Feet.
XIV.	Beacon Hill	13 57 24				13 57 23	
	Gringley	51 11 6,5				51 11 5	
	South end of Base	114 51 32,5				114 51 32	
		180 0 3					
		Gringley from Beacon Hill					75068,2
		Wherefore the mean distance from Gringley to Beacon Hill is 75068,1 Feet.					
XV.	Heathersedge	18 40 38,5	+0,29			18 40 38	
	Beacon Hill	138 9 16	—2,02			138 9 16	
	Gringley	23 10 6	+0,65			23 10 6	
		180 0 0,5		1,08	—0,58		
		Heathersedge from { Beacon Hill					92227,2
		Heathersedge from { Gringley					156384,8
XVI.	Sutton Ashfield	78 47 2	—1,01			78 47 1	
	Heathersedge	54 52 37,5	—0,24			54 52 35	
	Gringley	46 20 24	—0,22			46 20 24	
		180 0 3,5		2,45	+1,10		
		Sutton Ashfield from { Gringley					130309,7
		Sutton Ashfield from { Heathersedge					115339,9
XVII.	Orpit	80 28 57,25	—0,85			80 28 57	
	Heathersedge	39 8 38,5	—0,12			39 8 38	
	Sutton Ashfield	60 22 25,5	—1,00			60 22 25	
		180 0 1		2,03	—1,03		
		Orpit from { Heathersedge					101660,3
		Orpit from { Sutton Ashfield					73826,6

No. of triangles.	Names of stations.	Observed angles.	Diff.	Spherical excess.	Error.	Angles corrected for calculation.	Distances.
		° ′ ″	″	″	″	° ′ ″	Feet.
XVIII.	Hollan Hill -	44 43 32	—0,12			44 43 31	
	Sutton Ashfield -	113 49 9	—0,53			113 49 7	
	Orpit - -	21 27 20,5	—0,18			21 27 22	
		180 0 1,5		0,73	+0,77		
	Hollan Hill from { Sutton Ashfield - -						38375,2
	Hollan Hill from { Orpit - - - -						95975,3
XIX.	Bardon Hill - -	42 58 59,5	—0,69			42 58 59	
	Hollan Hill -	74 52 38	—1,03			74 52 37	
	Orpit - -	62 8 25	—1,01			62 8 24	
		180 0 2,5		2,75	—0,20		
	Bardon Hill from { Hollan Hill - - -						124454,7
	Bardon Hill from { Orpit - - -						135895,3
XX.	Castle Ring -	55 32 44	—0,94			55 32 43	
	Bardon Hill -	68 24 4,75	—1,02			68 24 3	
	Orpit - -	56 3 14,75	—0,90			56 3 14	
		180 0 3,5		2,85	+0,65		
	Castle Ring from { Orpit - - -						153235,2
	Castle Ring from { Bardon Hill - - -						136717,8
XXI.	Corley - -	72 32 46,5	—1,19			72 32 46	
	Castle Ring -	47 54 42,25	—0,86			47 54 42	
	Bardon Hill -	59 32 32,25	—0,94			59 32 32	
		180 0 1		2,93	—1,93		
	Corley from - { Bardon Hill - -						106357,3
	Corley from - { Castle Ring - -						123539,7
XXII.	Arbury Hill -	34 14 33,5	—0,98			34 14 33	
	Corley - -	107 20 14,25	—1,99			107 20 14	
	Bardon Hill -	38 25 13,25	—0,80			38 25 13	
		180 0 1		3,37	—2,37		
	Arbury Hill from { Bardon Hill - -						180426,0
	Arbury Hill from { Corley - - - -						117457,1

From the last triangle, we get 117457,1 for the distance between Corley and Arbury Hill. By the XI. triangle, the distance between those stations is 117463 feet; there is, therefore, a difference of nearly six feet between the two determinations; a quantity which cannot be considered unexpectedly great, as the side is more than twenty-two miles in length, and the whole series nearly two hundred miles long. If the computation had been carried on from Dunnose all the way up, the bases on Hounslow Heath and Salisbury Plain would have given the length of that on Misterton Carr about one foot greater than its measured extent. If the sides of the triangles contiguous to Corley and Arbury Hill be recomputed, from the mean distance between those stations, *viz.* 117460 feet, no doubt whatever can be justly entertained of the general accuracy of the whole. These mean distances, as I have before observed, will be used in the calculations of the total length of the meridional arc. From the Base in the north, I have numbered the triangles downwards: the reason is obvious.

Calculation of the meridional Distance between Dunnose and Clifton.

To do this, it will be right to compare the distances of the several stations from the respective perpendiculars, both of Dunnose and Clifton, as derived from the observed direction of each meridian.

In the Phil. Trans. for 1795 it will be seen, that the direction of the meridian was observed at the station on Dunnose, in 1795, the staff to which the pole star was referred being placed on Brading Down. The angle between that staff and the meridian, (see page 517 of that volume,) was found to be 21° 14′ 11″,5, as

derived from two double azimuths of the star, supported by several computed azimuths, applied to single but accurate observations.

The angle between Butser Hill and the staff at Brading Down, was 0° 15′ 35″,5. This, with the above angle, 21° 14′ 11″,5, and particular angles of the series, gives,

The Bearings of certain Sides from the Parallels to the Meridian of Dunnose.

Dunnose and Butser Hill	-	20°	58′	39″ NE
Butser Hill and Highclere	-	34	20	17 NW
Highclere and Nuffield	-	35	30	40 NE
Nuffield and Brill	-	4	51	15 NW
Brill and Arbury Hill	-	12	30	17 NW
Arbury Hill and Bardon Hill	-	7	42	57 NW
Bardon Hill and Orpit	-	21	21	9 NW
Orpit and Heathersedge	-	5	25	52 NW
Heathersedge and Beacon Hill	-	61	52	17 NE.

These bearings, and the respective sides, give the following distances on the meridian of Dunnose, *viz.*

	Feet.	Miles.
Dunnose and Butser Hill -	131263,0 =	24,86
Butser Hill and Highclere	122282,7 =	23,15
Highclere and Nuffield -	97984,7 =	18,56
Nuffield and Brill - -	91755,3 =	17,38
Brill and Arbury Hill -	143054,1 =	27,09
Arbury Hill and Bardon Hill	178792,4 =	33,86
Bardon Hill and Orpit -	126567,8 =	23,97
Orpit and Heathersedge -	101203,7 =	19,17
Heathersedge and Beacon Hill	43480,7 =	8,23
	1036334,4 =	196,27, the distance

between Clifton and the perpendicular to the meridian of Dunnose; which may be taken for the true length of the arc itself, as the distance of the former station from the meridian of the latter, is only 4770 feet.

If the angle between the meridian and the staff at Brading Down was observed accurately, there can be no doubt of the correctness of this determination; but, as it was right on my part to adopt measures for bringing it to some proper test, I observed, as before stated, the direction of the meridian at Clifton. The particulars were as follows.

Observed Angles between the Pole Star, when at its greatest Elongations from the Meridian of Clifton, and the Staff erected over the Station at Gringley on the Hill.

August, 1801.

Days.	Evenings.	Mornings.
9th. -	100° 45′ 46″	
10th. -	100 45 48,5	
11th. -	100 45 45,5	106° 39′ 34″
13th. -	100 45 39	106 39 22
16th. -	100 45 40,5	
17th. -	100 45 41	106 39 24
18th. -	100 45 39	106 39 28
19th. -	100 45 46,5	106 39 27.

If a mean of all the evening observations be taken, we shall get 100° 45′ 42″,8, for the angle between the staff at Gringley and the star when at its greatest eastern elongation from the merdian. In like manner, if a mean of all the morning observations be taken, we shall have 106° 39′ 27″, for the angle between the same staff and the star on the western side. Hence, half their

sum, 109° 42′ 35″, nearly, will be the angle between Gringley and the meridian of Clifton; and its south-eastern bearing 76° 17′ 25″. This, with certain angles of the series, gives the bearings of the following sides, *viz.*

Beacon Hill and Heathersedge -	61°	51′	50″	SW
Heathersedge and Orpit - -	5	26	19	SE
Orpit and Bardon Hill - -	21	21	36	SE
Bardon Hill and Arbury Hill -	7	43	26	SE
Arbury Hill and Brill - -	12	31	0	SE
Brill and White Horse Hill -	50	15	48	SW
White Horse Hill and Highclere	27	48	6	SE
Highclere and Butser Hill - -	34	20	49	SE
Butser Hill and Dunnose -	20	58	9	SW.

These bearings and sides give the following parallels to the meridian of Clifton.

	Feet.
Beacon Hill and Heathersedge	43490,4
Heathersedge and Orpit -	101202,6
Orpit and Bardon - -	126561,3
Bardon Hill and Arbury Hill -	178793,2
Arbury Hill and Brill -	143047,4
Brill and White Horse Hill -	93717,6
White Horse Hill and Highclere	96031,4
Highclere and Butser Hill -	122219,8
Butser Hill and Dunnose -	131270,2

The sum, 1036333,9 feet, is the distance between Dunnose and the perpendicular to the meridian of Clifton; or, as observed with regard to the sum of the parallels to the meridian of the former, the length of the arc itself.

There is, therefore, a difference of only half a foot, between the two results. We may, consequently, take 1036334 feet, for the distance required.

I have observed, in a former part of this account, that the zenith sector was placed $6\frac{1}{2}$ feet from the station at Dunnose, and $3\frac{1}{2}$ feet from that at Clifton, the new points being due south of the old. We must therefore add 3 feet to 1036334; which gives 1036337 feet, for the total length of the arc of the meridian.

The sum of the parallels to the meridian of Clifton, reaching down to Arbury Hill, is 450047,5 feet; and the distance of the latter from that meridian 1996 feet. This is, in fact, the meridional extent between the two old stations, as no correction is requisite. We must, however, subtract 30 feet from this distance, as the sector was put up $34\frac{1}{2}$ feet northward of the station on Arbury Hill. Therefore, $450047,5 - 30 = 450017,5$ feet, is the length of the arc comprized between the parallels of the new stations at Clifton and Arbury Hill: and, subtracting this from 1036337, we have 586319,5 feet, for the distance of this latter station from the point over which the sector was placed at Dunnose.

Although the zenith sector was taken to the Royal Observatory at Greenwich, rather with a view of collecting materials for finding the latitude of Dunnose, than to answer any other purpose, yet, as I am provided with the means of finding the meridional distance between those places, and that with sufficient accuracy, I shall go through the work in this place.

Distance between the Parallels of Latitude of Greenwich and Dunnose.

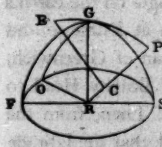
In the Phil. Trans. for 1795, the station on Beachy Head is shown to be 269328 feet from the perpendicular at Greenwich, and 58548 from its meridian. In Plate XVI. Fig. 2, of this account, let DPB be a great spheroidical triangle on the earth's surface, P the pole, and DB the two stations at Dunnose and Beachy Head. Let also PGM be the meridian of Greenwich, [G,] and M the point where the parallel of Beachy Head to the perpendicular at G cuts that meridian. Then, from the above values of GM and BM, it will be found, that the latitude of B is 1″,03 less than the latitude of M, and that too on any hypothesis of the earth's figure. Therefore, the distance in feet, between the parallels of B and G, is 269328 + 103 = 269431.

Now it has been shown, in the volume above referred to, (see page 522,) that the meridional distance between D and B is the mean of the two numbers 44258,6 and 44258,9 feet; and it must be remembered that, in deducing those conclusions, recourse was not had to matters of assumption, but to matters of fact, which were, the observed directions of the two meridians PD, PB, and the distance DB. Therefore, if 44259 feet be taken for the meridional distance between D and B, we shall have 269431 + 44259 = 313690 feet, for the space between the parallels of latitude of Greenwich and Dunnose.*

* In the Phil. Trans. for 1800, (see note to page 641,) in finding the value of the oblique arc between Black Down, in Dorsetshire, and Dunnose, I have used the expression $\frac{pm}{p+m-s.s} = d$; where d is the length of the required degree, p that of the great circle perpendicular to the meridian, m that of the degree of the meridian itself, and s the sine of the angle constituted by the oblique arc and the meridian.

We have then found the total length of the whole meridional arc, and also the distances of two intermediate points from either, or from both, of its extremities. And, to bring the whole

The demonstration of this rule I did not insert, on account of the previous length of the note alluded to; but I take this opportunity of supplying the omission, in the words of Mr. DALBY.



Having the length of the degree on the meridian, and also that of the degree perpendicular to it, at the same point; to find the length of a degree in any other given direction, supposing the earth to be an ellipsoid.

Let EP be one-fourth of the elliptic meridian; C the centre of the earth; CE, CP, the equatorial and polar semiaxes; G a given point on the meridian EP. Draw GR perpendicular to the meridian at G, meeting the axis PR in R; then RG is the radius of curvature of the ellipse, at the point G, which is perpendicular to the meridian at G.

Conceive another ellipsoid FGSO to touch the given one in the point G. Then, it is evident, that if the curvature be respectively the same in the direction of the meridian and the perpendicular, on both ellipsoids at the point G, the curvature will also be equal on both figures, in any other direction at that point. And the like is manifest in spheroids of any other kind.

Let M be the radius of curvature of the meridian at the point G; then, because RG is the radius of curvature in the perpendicular direction, if we take FS (at right angles to RG) $= s\sqrt{RG \times M}$, and about FS, the axis to the semidiameter RG, describe the ellipsoid FGSO, it will be *that* having the curvature of G the same as on the other ellipsoid at that point.

Let OGR be the plane of an ellipse, inclined to the meridian EGP, or to the plane FGS, in a given angle FRO, whose *sine* and *cosine* are s and c. Then, since RG, or rather its equal, is a semitransverse, in the plane FOSR, (which is perpendicular to RG,) to the semiconjugate RF, we shall have $\frac{RG^2 \times RF^2}{RG^2 c^2 + RF^2 s^2} = RO$, which, divided by RG, (RG being the semitransverse to RO in the perpendicular plane ROG,) gives $\frac{RG \times RF^2}{RG^2 c^2 + RF^2 s^2}$ for the radius of curvature of the inclined ellipse OG at the point G. But, because the lengths of the degrees are proportional to their radii of curvature, if we put m and p for the meridional and perpendicular degrees, then RF or $\sqrt{RG \times M}$ and RG may be expounded by $\sqrt{pm}$, and p; hence, the expression will become $\frac{pm}{pc^2 + ms^2}$, for the length

under one point of view for future use, we shall have the following

Arcs.

	Feet.	Miles.
1. Clifton and Dunnose -	1036337 =	196,27
2. Dunnose and Arbury Hill -	586320 =	111,05
3. Dunnose and Greenwich - -	313696 =	59,41
4. Clifton and Arbury Hill -	450017 =	85,23
5. Clifton and Greenwich - -	722641 =	136,86
6. Arbury Hill and Greenwich -	272624 =	51,63

Remark.

In calculating the distance between the parallels of latitude of two places, connected by means of a trigonometrical operation, regard must be had to their difference in longitude. If the triangles run nearly north and south, in which case stations must lie both east and west of the two meridians, it is sufficiently correct to proceed on the supposition of the earth's surface being a plane; but if, on the contrary, the triangles wholly diverge from the two meridians, or even partly do so, first running off obliquely and then returning again, a different

of the degree oblique to the meridian; or, putting $1 - s^2$ for c^2, and r for $p - m$, it will be $\frac{p\,m}{p - r\,s^2}$.

Corol. If d be the length of the oblique degree, then, since $d = \frac{p\,m}{p\,c^2 + m\,s^2}$, we have $p = \frac{s^2\,d\,m}{m - c^2\,d}$, and $m = \frac{c^2\,d\,p}{p - s^2\,d}$. And, if D be put for the length of another oblique degree at the same point, and S and C the *sine* and *cosine* of its inclination to the meridian, we shall get $m = \frac{S^2\,c^2 - C^2\,s^2}{S^2\,D - s^2\,d} \times D\,d$, and $p = \frac{S^2\,c^2 - C^2\,s^2}{c^2\,d - C^2\,D} \times D\,d$, the meridional and perpendicular degrees, exhibited in terms of the oblique degrees combined with the sines and cosines of their inclinations to the meridian. Therefore, an ellipsoid may be determined from the lengths of two oblique degrees in the same latitude.

We may likewise remark, from the nature of radii of curvature, at the same point G, that the expression $\frac{p\,m}{p - r\,s^2}$ will also give the oblique degree on different spheroids.

method must be pursued. The necessity giving rise to this, originates from the radii of curvature of the oblique degrees continually varying, and the angles of convergency, between the several sides and their respective meridians, remaining unknown.

It must be remembered, that the sides of the several triangles projected over the country, in this Survey, are not to be considered as so many distances on the earth's surface, but the lengths of the chord lines subtended by arcs. Therefore, it is manifest that, strictly speaking, all the chord angles should be used, and not the horizontal ones; with which, after the bearing of the first side with the meridian has been reduced to some plane beneath the earth's surface, a number of chord lines in the plane of that meridian are to be computed; the sum of which, augmented by the differences between those chords and their respective arcs, will give the true meridional distance. I have been at the trouble to calculate the distance between Clifton and Dunnose on this principle; and find the length of my arc to be 1036339.5 feet; which is, about $2\frac{1}{2}$ feet more than the distance determined by the other mode of computation. An advantage, however, attending a calculation on the principle now spoken of, is the ability of calculating, pretty nearly, the azimuth of any one station from an extremity of the arc. This, if the instrument with which the direction of the meridian is observed be not well divided, or otherwise not exactly fit for the operation, is necessary, and should be always done. The angle at Clifton, between Gringley on the Hill and the meridian, was observed to be 76° 17′ 25″. According to my computation in the way spoken of, that angle is 76 17′ 30″. A difference of 5″, working all the way up from Dunnose through an arc of 2° 50′, is as small as can be expected, and serves to prove that the angles of

the triangles, as well as the observed direction of the meridians, are consistent. I have given the meridional distance between Clifton and Dunnose, bearings of the sides, &c. deduced from the most simple of the two methods; first, because the result is sufficiently accurate; secondly, because it places within general reach, the means of examining this part of my operation. In attending to this remark, it must be remembered, that a line from Dunnose perpendicular to the meridian of Clifton, is only 4853 feet.

SECTION SECOND.

Operations at the Station on Dunnose, the Southern Extremity of the Arc, with the Zenith Sector. May and June, 1802.

On the 8th of May, the circular or large theodolite was placed over the point selected for a new station: its distance was $6\frac{1}{2}$ feet from the gun, and in a direction due south. The following objects were then observed, the readings of which, on the graduated limb, were as follows.

Sir R. Worsley's obelisk (the top) -	113° 14′ 28″
East Cowes sea mark - - -	1 46 36,5
Luttrell's Folly - - -	177 56 25
Vane on the top of Portsmouth Church	40 6 44,5
Sir R. Worsley's obelisk, a second time	113 14 24,25

The above objects were observed, in order that no possible mistake might result; as (though not probable) accidental circumstances might have given rise to a wrong statement of the bearing of some one of the number, (except Portsmouth Church,) in the account of 1795. Omitting the obelisk, the

bearings of the other objects, as extracted from that Paper, will be as follows.

Luttrell's Folly	23°	0′	44″	NW	from the meridian of Dunnose.
East Cowes sea mark	19	11	19	NW	
Portsmouth Church	19	9	40	NE	

If, from the readings on the limb, the angles between the obelisk and the other objects be taken, and applied to the last-mentioned bearings, we shall get the angle between the obelisk and the meridian, 87° 42′ 40″
35
45 } Mean, 87° 42′ 40″.

May 9th. Erected the observatory, drove four long stakes into the ground, and brought their several heads into the same horizontal plane. Then erected the stand, set up the sector, and adjusted the axis level, and the axis itself; determined the exact weight the plumb-line would bear, and then examined how much the cross wires were out of their proper positions, as follows.

The stand being firmly screwed down to the stakes, the sector was turned on its axis, till the pointed top of Sir Richard Worsley's obelisk appeared in the field; it was then clamped to the azimuth circle, but subject to a small motion by turning an adjusting-screw. The pointed apex was then made to appear as just vanishing under the wires; in which situation of things, the side telescope was turned round, and laid in its several positions on the brass frame attached for its reception to the side of the sectorial tube; the top of the obelisk appearing as a vanishing point under the wires. On whichever face of its squares it was made to rest, the vernier of the azimuth circle read off to 84° 5′. The little telescope was then taken out of its frame, and the

sector turned half round. It was then again introduced into its supports, and the interior stand moved, till the wires in the focus of the lateral telescope appeared on the obelisk as before. The vernier was then examined, which again stood at 84° 5′. This being settled, the sector was turned round, till its vernier stood at 176° 22′ on the azimuth circle, in which situation, the plane of the divided arc was necessarily parallel to that of the meridian. The task of observation then commenced, and the performance of it was as follows.

Observations made at Dunnose, to determine the Zenith Distance of β Draconis.

Point on the Limb, 1° 50′ North.

Day of the month.	Face of the arch, W. or E.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Thermometer. Below.
1802		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
May 11	W	9 4,82	9 17,9	1 50 0 13,08	1 49 46,90	28,85	43,5	43,5
13	E	9 16,95	8 56,0	19,95	40,02	28,85	36,5	38,0
14	W	9 34,25	9 47,5	13,25	46,73	28,92	34,5	34,5
16	E	8 32,16	8 14,0	18,16	41,81	28,82	35,5	34,5
June 5	W	6 23,00	6 30,0	7,00	52,99	28,45	51,5	51,5
8	E	8 14,02	8 2,0	12,02	47,96	28,49	52,0	51,8
11	W	6 57,40	7 2,6	4,20	55,79	28,54	52,5	52,0
13	E	9 39,50	9 29,5	10,00	49,98	28,79	53,0	52,7
14	W	8 19,29	8 23,7	4,41	55,58	28,86	54,2	53,0
16	E	3 56,61	3 47,0	9,61	50,37	28,75	59,5	60,0
17	W	8 38,52	8 41,5	2,98	57,02	28,82	56,1	58,0
18	E	11 31,87	11 21,5	10,37	49,61	28,81	52,0	51,0
20	W	8 53,27	8 54,2	0,93	59,07	29,03	57,5	58,0
21	E	10 27,05	10 19,7	7,35	52,64	28,99	56,5	55,5

Observed Zenith Distances of γ Draconis.

Point on the Limb, 0° 50′ North.

Day of the month.	Face of the arch, W. or E.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
May 10	E	10 15,52	13 48,1	0 50 3 32,75	0 53 30,10	29,0	—	45,0
11	W	9 38,66	5 56,4	41,26	38,62	28,85	43,9	43,5
13	E	8 47,30	12 81,4	34,10	31,45	28,85	36,5	38,0
14	W	7 32,38	3 49,2	42,18	39,54	28,92	34,5	34,5
16	E	9 40,00	13 15,2	34,20	31,55	28,82	35,5	36,5
June 11	W	7 20,70	3 29,5	50,20	47,58	28,34	53,5	52,5
13	E	9 36,35	13 20,3	42,95	40,31	28,79	52,5	52,3
14	W	8 25,26	4 33,4	50,86	48,24	28,26	54,3	53,0
16	E	9 48,33	14 37,4	45,07	43,44	28,75	59,5	60,0
17	W	8 32,66	4 39,4	52,26	49,64	28,82	56,0	58,0
18	E	11 32,77	15 17,9	44,13	41,50	28,8	52,0	51,0
20	W	8 9,48	4 17,0	51,48	48,86	29,97	58,6	57,0
21	E	11 32,92	15 40,0	47,08	44,45	28,83	56,0	55,5

Observed Zenith Distance of 45 d Draconis.

Point on the Limb, 6° 15′ North.

June 13	E	9 27,76	10 53,1	6 15 1 25,34	6 16 24,48	28,8	49,5	51,0
14	W	9 23,81	7 48,5	34,31	33,30	28,86	54,0	53,0
16	E	10 18,90	11 46,5	27,60	26,74	28,77	59,0	59,5
18	W	11 11,65	9 32,9	37,75	36,91	28,8	58,5	52,7
20	E	8 18,20	9 46,7	28,50	27,64	28,97	56,0	55,5
21	W	11 31,03	9 52,7	37,33	36,49	28,99	56,0	55,5

Observed Zenith Distance of 46 c Draconis.

Point on the Limb, 4° 40′ North.

June 13	E	9 34,85	12 46,0	4 40 3 11,15	4 43 8,46	28,8	49,5	51,0
14	W	8 16,17	4 53,0	20,17	17,50	28,86	51,7	50,5
16	E	13 15,62	10 27,0	11,38	8,69	28,77	59,0	59,5
18	W	11 10,40	7 41,3	18,10	15,42	28,8	52,7	50,5
20	E	8 32,10	11 47,0	14,90	12,22	28,97	58,4	57,0
21	W	11 5,13	7 43,1	21,03	18,36	28,99	56,0	55,5

Observed Zenith Distance of 51 Draconis.

Point on the Limb, 2° 25′ North.

Day of the month	Face of the arch, W. or E.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
June 13	E	7 42,00	13 11,5	2 20 3 28,50	2 23 25,84	28,8	49,5	51,0
14	W	8 10,63	4 33,3	36,33	33,68	28,9	51,8	50,5
16	E	9 0,0	12 28,8	28,80	26,14	28,8	59,0	59,5
18	W	10 48,27	7 11,5	36,77	34,12	28,8	50,2	50,0
20	E	8 47,43	12 21,0	32,57	29,92	29,0	55,0	56,0
21	W	11 2,23	7 24,5	36,75	34,08	29,0	53,5	55,0

Observed Zenith Distance of μ Draconis.

Point on the Limb, 4° 5′ North.

May 11	W	9 18,20	7 31,6	4 5 1 45,60	4 6 44,73	28,85	43,5	43,5
13	E	13 3,04	11 39,0	46,01	35,17	28,85	40,5	41,0
14	W	10 2,03	8 18,4	42,63	41,80	28,92	36,3	38,5
June 9	E	8 12,56	9 57,1	44,54	43,71	28,51	51,5	51,0
13	E	9 29,34	11 15,8	45,46	44,63	28,79	53,5	51,5
14	W	8 29,56	6 34,7	53,86	53,05	28,86	53,5	54,0
16	E	4 9,66	5 56,0	40,34	45,51	28,75	59,5	60,0
17	W	8 45,33	6 50,5	53,83	53,02	28,82	56,0	58,0
18	E	11 44,83	13 34,0	48,17	47,35	28,80	52,0	51,1
20	W	8 44,96	6 47,0	54,96	54,15	29,0	58,2	58,0
21	E	10 34,60	12 25,0	49,40	48,58	28,99	55,8	55,5

Observed Zenith Distance of 16 Draconis.

Point on the Limb, 2° 40′ North.

May 11	W	10 2,08	7 43,0	2 40 2 18,08	2 42 16,30	28,85	43,5	43,5
14	W	10 27,15	8 9,0	18,15	16,37	29,92	36,5	37,2
16	W	8 31,87	6 14,0	17,87	16,09	28,82	39,0	39,9
June 5	W	9 38,25	7 11,5	26,75	24,99	28,54	53,5	52,0
13	E	4 28,90	1 48,3	39,60	37,86	28,86	52,0	51,5
14	W	8 31,63	6 4,0	27,63	25,87	28,86	53,5	54,0
16	E	3 51,90	6 14,5	21,60	19,83	28,78	61,0	60,2
18	E	11 28,70	13 50,1	21,40	19,63	28,80	51,5	52,7
20	W	8 25,61	5 55,2	29,41	27,65	28,95	57,7	58,5

Observed Zenith Distance of 1 *ν Cygni.*
Point on the Limb, 2° 20′ *North.*

Day of the month.	Face of the arch, W. or E.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above	Thermometer. Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
June 13	E	9 26.60	12 33.5	2 20 3 6,90	2 23 4,20	28,8	50,0	50,5
14	W	5 54,98	2 37.0	17,98	15,30	28,9	52,1	50,0
16	E	8 49.45	6 52,9	1 55,55	5,26	28,8	59,9	59,0*
18	W	10 12,05	6 58,8	2 20 3 16,25	13,57	28,8	50,1	50,0
20	E	9 9,83	12 20,0	10,17	7,48	29,0	54,9	56,10
21	W	11 1,83	7 44.2	16,63	13,95	29,0	55,0	53,5

* Point on the limb 2° 25′.

Observed Zenith Distance of 10 *ι Cygni.* ‡
Point on the Limb, 0° 40′ *North.*

June 13	E	9 30,95	10 55,2	0 40 1 24,25	0 41 23,39	28,8	50,0	50,5
14	W	6 50,05	4 51,8	32,25	31,40	28,9	51,7	50,5
16	E	8 43,00	10 9,5	25,50	24,64	28,8	60,0	59,0
18	W	9 38,90	8 26,0	32,90	32,05	28,8	50,2	50,0
20	E	8 30,78	10 0,0	28,22	27,36	29,1	55,0	56,0
21	W	11 19,80	9 45,1	33,70	32,85	28,9	55,0	55,5

Observed Zenith Distance of γ *Ursæ.*
Point on the Limb, 4° 10′ *North.*

May 9	E	11 42,53	12 14.6	4 10 0 31,07	4 10 31,12	—	—	—
10	E	11 10,60	11 42,5	31,90	31,95	29,0	52,0	52,0
11	W	8 34,32	7 54 4	38,92	38,98	28,8	50,5	51,5
13	E	9 54,86	10 29,5	33,64	33,69	28,8	45,7	44,3
24	E	10 1,47	10 34,5	33,03	33,08	28,9	38,5	38,5
15	W	7 15,49	6 33,6	40,89	40,96	28,9	41,0	41,5
17	E	8 54,00	9 29 5	34,50	34,56	28,8	46,0	42,5
20	E	13 43,03	14 18,1	34,07	34,13	28,7	50,5	51,0
June 5	W	9 21,10	8 35,5	43,60	43,67	28,4	53,0	55,1
6	E	8 58,90	9 36,2	37,30	37,36	28,5	55,5	58,5
12	E	5 46,50	6 22,4	34,90	34,96	28,6	54,0	54,0†
13	W	10 40,70	9 56 4	43,30	43,37	28,7	59,1	59,0
14	W	7 16,40	6 53,0	42,40	42,47	28,9	60,4	59,3
16	E	9 3,20	9 41,1	38,00	38,06	28,8	72,0	69,5

† Imperfect observation.

‡ In page 417, 10 ν Cygni should be 10 ι, ξ Ursæ should be ζ, 85 ν Herculis should be 85 ι, and ν Herculis should be υ.

Observed Zenith Distance of η Ursæ.
Point on the Limb, 0° 15′ South.

Day of the month.	Face of the arch. W. or E.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
May 10	E	10 6,74	6 8,6	0 15 3 57,14	5 18 54,53	29,0	49,1	49,0
13	E	9 48,22	5 49,1	58,12	55,51	28,9	40,5	41,0
14	W	10 47, 4	14 39,6	50,86	48,24	28,9	36,5	38,5
15	E	10 9,99	6 11,1	57,89	55,28	28,9	41,0	41,5
16	W	9 13,31	13 5,0	50,69	48,07	28,8	39,0	39,9
17	E	9 0,46	5 3,2	56,26	53,65	28,8	46,0	42,5
June 5	W	7 58,15	11 46,3	47,15	44,52	28,5	52,3	52,3
8	E	9 6,37	5 11,6	53,72	51,10	28,5	52,0	56,0
11	W	9 28,50	13 12,7	43,20	40,57	28,5	52,0	55,5
12	E	5 32,60	1 59,0	52,60	49,98	28,6	57,5	56,0
13	W	10 14,50	14 4,0	48,50	49,87	28,7	56,5	56,5
14	E	7 47,52	4 0,4	47,12	44,49	28,8	57,0	56,5 *
16	W	9 4,21	12 49,7	45,49	42,86	28,8	64,0	63,5
18	W	9 14,50	13 0,5	45,00	42,37	28 8	50,5	57,5
20	E	9 6,03	5 13,9	51,13	48,41	28,8	67,0	70,5
21	E	12 45,00	8 57,5	50,50	47,87	28,9	55,5	56,0

* Doubtful.

Observed Zenith Distance of ζ Ursæ.
Point on the Limb, 5° 20′ North.

May 11	W	9 19,98	8 44,3	5 20 0 34,68	50 20 34,74	28,8	48,9	49,5
13	E	9 37,00	10 5,5	27,50	27,54	28,8	45,1	44,1
17	E	8 49,96	9 20,5	29,54	29,59	28,8	46,0	42,3
June 5	W	8 31 92	7 51,9	39,02	39,08	28,5	52,3	52,3
8	E	8 56,50	9 28,1	30,60	30,65	28,5	52,0	56,0
11	W	9 36,93	8 55,6	40,33	40,00	28,5	54,0	55,0
14	E	7 47,74	8 23,0	34,26	34,32	28,5	60,5	59,5
17	E	9 33,12	10 8,2	34,08	34,14	28,8	64,0	65,0
18	W	9 28,30	8 45,0	42,30	42,37	28,7	57,5	59,5
20	E	8 54,12	9 30,2	35,08	35,14	28,8	67,0	70,5

Observed Zenith Distance of 85 ι Herculis.
Point on the Limb, 4° 25′ South.

May 10	E	15 16,87	9 50,6	4 25 5 25,27	4 30 20,80	29,0	45,5	45,5
13	E	8 28,70	3 2,5	26,20	21,73	28,8	40,5	41,0
14	W	8 24,16	13 43,0	18,84	14,36	28,9	34,5	34,5
16	E	9 36,40	4 11,2	25,20	20,23	28,8	35,5	35,5
June 14	W	8 25,36	13 33,6	8,24	3,74	28,8	54,0	53,0

Observed Zenith Distance of υ Herculis.

Point on the Limb, 4° 0′ South.

Day of the month.	Face of the arch, W. or E.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches	°	°
May 11	W	9 25,06	10 55,0	4 0 1 29,94	4 1 29,09	28,8	43,5	43,5 *
13	E	10 3,86	8 12,2	50,66	49,84	28,8	40,5	41,0
14	W	9 44,22	11 27,6	42,38	41,55	28,9	34,5	35,5
16	W	2 56,33	4 40,3	42,97	42,14	22,8	39,0	39,9
June 5	W	6 25,10	8 3,6	37,50	36,66	28,4	50,5	51,0
11	W	9 26,10	11 21,0	53,90	53,09	28,5	53,5	52,0
13	E	9 58,25	8 17,0	41,25	40,42	28,8	52,0	51,5
14	W	9 27,50	11 3,5	35,00	34,16	28,7	54,7	54,5
16	E	3 53,47	2 13,0	40,47	39,63	28,8	61,0	60,2
18	E	11 42,00	13 23,0	40,00	39,17	28,8	51,5	52,7
20	E	9 34,90	7 53,4	40,50	39,66	28,9	57,7	52,5

* Imperfect observation.

Observed Zenith Distance of 52 Herculis.

Point on the Limb, 4° 15′ South.

May 13	E	9 52,55	7 32,0	4 15 2 20,55	4 17 18,78	28,8	40,5	41,0
14	W	10 16,56	12 30,4	13,84	12,06	28,92	34,5	35,5
16	E	8 21,44	6 1,0	19,84	18,07	28,8	39,0	39,9
June 8	E	8 9,40	5 55,0	13,40	11,62	28,5	52,5	55,5
11	W	9 29,24	11 34,5	5,26	3,46	28,5	53,5	52,0
13	E	9 33,39	7 21,4	11,99	10,20	28,8	53,5	51,5
14	W	8 28,36	10 32,2	3,84	2,04	28,7	53,5	54,0
16	E	9 8,60	6 56,5	11,11	9,32	28,8	59,5	60,0
17	W	8 57,87	11 4,0	5,13	3,33	28,8	57,5	58,0
18	E	11 39,57	9 31,1	8,47	6,68	28,8	51,5	52,7 †
20	W	8 44,61	10 48,0	3,39	1,59	28,9	57,7	58,5
21	E	10 7,00	7 56,4	9,60	7,81	28,9	59,5	57,5

† Imperfect observation.

Observed Zenith Distance of 22 τ Herculis.

Point on the Limb, 3° 45′ South.

Day of the month.	Face of the arch, W. or E.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer, Above.	Thermometer, Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
May 10	E	11 1,72	6 0,7	3 45 5 1,02	3 49 56,51	29,0	—	49,0
11	W	9 28,35	14 21,1	4 51,75	48,23	28,8	43,5	43,5
13	E	9 56,10	4 57,0	58,10	54,59	28,8	40,5	41,0
14	W	10 26,95	15 17,8	49,85	46,32	29,9	36,5	38,5
16	W	8 27,50	13 19,0	50,50	46,98	28,8	39,0	39,9
June 5	W	6 24,95	11 10,2	44,25	40,72	28,4	50,5	51,0
8	E	8 46,08	3 50,7	49,38	45,85	28,5	50,5	52,5
11	W	9 31,31	14 14,4	42,09	38,55	28,5	53,5	52,0
13	E	9 35,50	4 46,5	48,00	44,47	28,8	52,0	51,5
14	W	9 3,82	13 45,7	41,88	38,34	28,8	53,5	54,0
17	W	8 37,38	13 19,6	41,22	37,68	28,8	57,5	58,0
18	E	11 41,16	6 53,5	46,66	43,11	28,8	51,5	52,7
20	W	8 44,15	13 27,0	41,85	38,31	28,9	57,7	58,5
21	E	10 22,13	5 34,3	46,83	43,30	29,0	59,5	57,6

Observed Zenith Distance of Capella.

Point on the Limb, 4° 50′ South.

May 11	E	10 37,73	10 29,0	4 50 0 8,73	4 50 8,74	28,9	64,0	65,1
12	W	9 16,65	9 18,2	1,55	1,55	28,7	63,5	66,0
13	E	9 42,06	9 34,4	7,66	7,07	28,8	57,4	54,9
15	W	8 38,83	8 39,4	0,57	0,57	28,7	53,0	58,1
June 8	W	8 39,52	8 42,5	2,98	2,98	28,4	63,2	60,1
11	E	9 0,74	8 53,0	12,74	12,74	28,4	65,5	62,5
15	W	10 26,53	10 31,4	4,87	4,87	28,8	78,0	73,0
16	E	8 48,20	8 31,5	16,70	16,73	28,7	72,0	69,5
21	W	12 24,35	12 30,9	6,55	6,56	28,8	71,0	68,5
22	W	5 48,80	5 52,9	4,04	4,05	28,6	86,0	79,1

Operations at the Station near Clifton, the northern Extremity of the Arc, with the Zenith Sector. July and August, 1802.

On the 19th of July, the observatory and zenith sector were erected at the station, and the angle between the spindle of the weathercock on Laughton Spire and a staff at Gringley on

the Hill, was observed on different arches of the large theodolite; the results being as follows, *viz.* 78° 13′ 32″ / 34 / 35 / 32 } Mean 78° 13′ 33″.

In a former article it has been shown, that Gringley is 76° 17′ 25″ south-east of the meridian of Clifton; therefore, 78° 13′ 33″ − 76° 17′ 25″ = 1° 56′ 8″, is the bearing of Laughton Spire from that meridian. The instrument, being otherwise adjusted for observation, was then brought into the plane of it, by setting off 1° 56′ 8″ on the azimuth circle; the permanency of the line of collimation of the lateral telescope having been previously ascertained.

Observations made at Clifton, to determine the Zenith Distance of β Draconis.

Point on the Limb, 1° 0′ South.

Day of the month.	Face of the arch, E. or W	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Thermometer. Below.
		rev. div.	div.	° ′ rev. div.	° ′ ″	Inches.	°	°
July 20	W	12 1,0[illegible]2	14,8	1 0 0 13,76	1 0 13,78	28,8	58,0	56,0
22	W	7 53,33	13 13,0	17,67	15,52	28,7	54,0	54,5
26	E	13 27,55	13 6,8	20,75	20,78	28,8	64,2	64,3
28	W	9 21,94	9 32,3	10,36	10,38	28,8	59,5	58,5
29	E	9 3,13	8 44,1	18,03	18,06	28,8	56,5	57,5
31	W	9 34,59	9 44,1	9,51	9,52	29,0	57,2	56,5
Aug. 1	E	8 36,00	8 18,5	17,50	17,53	29,2	59,5	57,2
3	W	8 57,87	9 8,9	10,03	10,05	29,16	68,0	64,5
5	E	8 11,26	7 53,8	16,46	16,48	29,0	71,5	73,2
7	W	8 51,74	9 1,6	8,86	8,87	28,9	67,2	66,1
8	E	8 14,84	7 57,9	15,94	15,96	28,9	65,1	65,1
12	E	11 7,98	10 50,6	16,38	16,41	29,15	58,1	58,0
13	W	8 22,00	8 30,4	8,40	8,41	29,3	61,2	61,1
17	E	8 30,33	8 15,8	14,53	14,55	29,1	70,5	71,0
18	W	8 46,62	8 54,7	8,08	8,09	28,8	70,1	70,3

Observed Zenith Distance of γ Draconis.

Point on the Limb, 1° 55′ South.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
July 20	W	11 49,24	13 12,8	1 55 1 22,56	1 56 21,69	28,9	56,5	55,0
21	E	7 23,81	5 53,7	29,11	28,26	28,5	53,0	52,2
22	W	7 54,31	9 17,1	21,79	20,92	28,7	54,5	54,5
23	E	3 46,15	2 18,9	27,25	26,39	29,0	56,1	56,1
26	W	9 8,47	10 29,5	21,03	20,16	28,8	64,0	64,0
28	E	9 35,56	8 9,6	25,96	25,11	28,8	56,2	57,3
29	W	8 44,41	10 4,5	19,09	19,03	29,0	56,5	56,5
Aug. 1	W	8 41,22	10 3,0	20,78	19,91	29,2	59,5	57,0
3	E	9 7,59	7 40,3	26,29	25,43	29,1	68,0	64,5
5	E	7 50,50	6 25,0	25,50	24,64	29,0	73,0	71,0
7	W	9 7,55	10 24,6	17,05	16,18	28,9	64,2	65,2
12	E	11 7,56	9 42,7	23,86	23,00	29,1	57,5	57,5
13	W	8 12,48	9 29,4	16,92	16,04	29,3	63,0	61,2
17	E	8 10,32	6 46,0	23,32	22,46	29,0	69,5	70,5
18	W	8 32,97	9 48,5	15,53	14,65	28,8	70,0	70,1

Observed Zenith Distance of 45 d Draconis.

Point on the Limb, 3° 25′ North.

July 22	W	7 35,91	6 10,5	3 25 1 25,41	3 25 24,56	28,7	54,0	53,0
26	W	8 36,67	7 11,1	25,57	24,71	28,8	64,6	63,5
29	W	8 53,36	7 26,6	26,86	26,02	28,8	56,5	56,5
31	E	13 50,53	14 51,0	20,47	19,60	29,0	55,0	55,2
Aug. 7	W	8 47,50	7 18,6	28,90	28,04	28,9	65,0	64,0
12	E	11 9,60	12 31,0	21,40	20,53	29,2	55,5	55,5
13	W	8 10,99	6 38,9	31,09	30,24	29,3	60,1	59,1
17	E	8 14,53	9 38,9	24,37	23,51	29,0	71,0	69,5
18	W	8 15,03	6 41,3	32,73	31,88	28,8	—	68,0

Observed Zenith Distance of 46 c Draconis.

Point on the Limb, 1° 55′ North.

Day of the month.	Face of the arch E. or W	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
July 20	W	12 7,00	8 55,8	1 50 3 10,20	1 53 7,51	28,9	55,5	55,5
22	W	7 28,12	9 21,4	1 55 1 52,28	8,53	28,7	54,0	53,1
28	E	9 29,68	7 31,3	57,38	3,43	28,8	57,2	55,5
31	E	9 29,77	7 31,7	57,07	7,74	29,0	55,3	55,5
Aug. 3	E	8 55,40	7 0,6	54,80	6,01	29.1	04,0	63,5
5	E	7 11,47	5 15,8	54,67	5,14	29.0	73,5	71,5
7	W	6 37,64	10 26,6	47,96	12,86	28,9	65,2	64,2
12	E	11 3,15	9 9,0	53,15	7,66	29,2	55,5	59,1
13	W	8 6,41	9 52,5	46,09	14,73	29,3	60,0	59,0
17	E	8 25,75	6 32,3	52,45	8,36	29,0	71,2	69,5
18	W	8 20,25	10 6,3	45,05	15,78	28,8	71,0	68,0

Observed Zenith Distance of 51 Draconis.

Point on the Limb, 0° 20′ South.

July 28	E	9 31,75	7 50 7	0 20 1 40,05	0 29 39,21	28,8	55,0	55,0
31	E	9 29,90	7 48,5	40,04	39,56	29,0	55,0	55,5
Aug. 5	E	7 11,71	5 32,6	38,11	37,27	29,0	71,0	69,2
7	W	8 48,70	10 19,5	29,80	28,95	28,9	63,5	63,5
9	W	9 6,30	10 35,3	29.00	28,15	28,9	66,5	65,5
12	E	11 7,00	9 30,5	35,50	34,66	29,2	55,5	59,0
13	W	8 1,71	9 29,5	27,79	26,93	29,3	60,2	59,1
17	E	8 27,62	6 52,0	34,62	33,77	29,0	70,1	70,2
18	W	8 20,96	9 47,4	26,44	25,58	28,8	67,0	67,0

Observed Zenith Distance of μ Draconis.

Point on the Limb, 1° 15′ North.

July 20	W	11 51,87	10 9,3	1 15 1 42,57	1 16 41,73	28,9	58,0	56,0
28	W	9 11,90	7 26,9	44,00	43,17	28,8	58,2	58,5
29	E	9 11,32	10 51,0	39,68	38,84	28,8	56,5	57,5
30	W	9 55,53	8 10,0	45,53	44,70	28,8	59,0	57,5
Aug. 12	E	11 17,11	12 57,3	40,19	39,25	29,15	69,2	65,2
13	W	8 21,48	6 31,5	48,98	48,16	29,32	62,0	63,5

Observed Zenith Distances of 16 *Draconis.*

Point on the Limb, 0° 5′ *South.*

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
July 29	E	9 26,41	6 31,7	2 53,71	2 53,99	28,8	59,7	59,5
30	W	9 38,07	12 26,0	46,93	45,20	28,8	62,5	60,1
Aug. 5	E	8 17,70	5 23,0	53,70	51,98	29,1	79,1	78,1

Observed Zenith Distances of 1 *x Cygni.*

Point on the Limb, 2° 25′ *North.*

July 20	W	13 45,26	15 42,5	0 25 1 56,24	0 26 55,43	28,9	56,5	55,0
22	W	9 12,66	11 10,3	56,64	55,83	28,7	54,0	54,0
26	W	9 42,42	11 39,1	55,68	54,87	28,8	64,5	63,5
28	E	9 29,47	7 27,2	2 2,27	27 0,47	28,8	55,2	55,2
29	W	9 3,65	11 7,4	3,75	1,95	28,9	56,9	55,0
30	W	9 43,53	11 37,3	1 52,77	26 51,95	28,7	57,0	55,0
31	E	9 30,77	7 28,5	2 2,27	27 0,47	29,0	55,0	55,0
Aug. 5	E	7 8,34	5 9,1	1 58,24	26 57,43	29,0	71,2	69,2
7	W	8 46,45	10 39,9	51,55	50,73	28,9	63,3	63,3
9	W	8 32,50	10 24,6	51,10	50,28	28,9	66,0	65,0
12	E	10 42,00	8 43,0	58,00	57,19	29,2	55,5	59,5
13	W	8 1,11	9 50,9	49,79	48,97	29,3	60,0	59,0
17	E	8 25,55	6 30,2	54,35	53,54	29,0	71,0	69,5
18	W	8 27,85	10 17,0	48,15	47,33	28,8	66,0	66,0

Observed Zenith Distances of 10 *i Cygni.*

Point on the Limb, 2° 10′ *South.*

July 20	W	13 51,27	12 27,2	2 10 1 24,07	2 8 36,79	28,9	56,5	55,0
28	E	9 22,60	10 42,5	19,90	40,97	28,8	57,3	55,5
29	W	9 8,23	7 38,5	28,73	32,12	28,8	56,7	56,5
30	W	9 31,50	8 4,0	27,50	33,36	28,7	55,5	57,5
31	E	9 19,20	10 39,5	20,30	40,57	29,0	55,0	55,2
Aug. 1	W	9 2,40	7 34,1	27,30	33,56	29,2	59,2	57,2
5	E	7 0,70	8 23,2	22,50	38,36	29,0	68,5	68,5
7	W	8 50,33	7 21,5	28,83	32,02	28,9	62,2	63,2
9	W	8 47,48	7 18,0	29,48	31,37	28,9	65,5	66,5
12	E	10 37,36	12 1,0	22,64	38,22	29,2	55,0	59,0
17	E	8 21,50	9 47,0	25,50	35,36	29,0	61,9	68,9
18	W	8 29,25	6 54,7	33,55	27,30	28,8	66,0	66,0

Observed Zenith Distance of γ Ursæ.

Point on the Limb, 1° 20′ North.

Day of the month.	Face of the arch. E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
Aug. 17	E	8 58,45	9 9,9	1 20 0 10,45	1 20 10,42	29,3	89,0	83,6

Observed Zenith Distances of η Ursæ.

Point on the Limb, 3° 5′ South.

July 23	W	9 1,35	13 5,0	3 5 4 3,65	3 9 0,05	29,0	62,5	62,5
26	W	9 26,00	13 30,9	4,90	1,30	28,9	78,0	78,2
Aug. 4	W	8 40,50	12 46,0	5,50	1,90	29,2	79,3	79,5
8	E	7 34,74	3 22,0	17,74	9,15	29,0	76,0	73,0
17	E	8 52,05	4 38,5	13,45	9,80	29,14	88,0	81,5

Observed Zenith Distances of ζ Ursæ.

Point on the Limb, 2° 30′ North.

July 29	E	9 8,82	9 21,5	2 30 0 12,68	2 30 12,70	28,8	69,0	65,5
Aug. 5	W	8 40,97	8 22,5	18,47	18,50	29,1	79,5	78,0
8	E	8 25,15	8 37,0	11,83	11,87	29,0	69,0	65,5
9	W	8 49,00	8 29,4	14,60	19,62	28,9	80,0	80,0
17	E	9 10,43	9 22,0	11,57	11,59	29,4	85,1	80,1

Observed Zenith Distances of 85 ι Herculis.

Point on the Limb, 7° 20′ South.

July 20	W	11 50,28	12 6,0	7 20 0 14,72	7 20 14,74	28,9	55,5	55,5
23	E	3 50,07	3 28,5	11,57	21,60	29,0	56,1	56,1
27	W	9 30,92	14 47,4	15 5 16,48	12,00	28,8	56,0	57,0
30	W	10 15,40	10 26,5	20 0 11,10	11,12	29,0	57,1	56,2
Aug. 1	W	9 6,18	9 17,0	10,82	10,84	29,2	59,5	57,2
5	E	8 2,52	7 42,0	19,52	19,75	29,0	73,0	71,0
7	W	9 17,54	9 29,0	11,46	11,48	28,9	67,2	66,1
17	E	8 15,52	7 56,0	18,52	18,55	29,0	70,5	71,2

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Observed Zenith Distances of υ Herculis.

Point on the Limb, 6° 50′ South.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Thermometer. Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
July 21	E	8 11,5	6 16,6	6 50 1 53,7	6 51 52,89	28,5	55,5	54,5
29	E	9 14,1	7 17,0	56,1	55,29	28,8	60,7	61,5
30	W	7 57,8	9 48,8	46,0	47,17	28,8	62,5	60,0

Observed Zenith Distances of 52 Herculis.

Point on the Limb, 7° 5′ South.

July 28	W	8 58,72	11 15,5	7 5 2 15,78	7 7 14,00	28,8	58,5	58,5
29	E	9 11,35	6 47,0	23,35	21,58	28,8	59,7	59,5
30	W	10 1,29	12 16,0	14,71	12,93	28,8	61,0	59,0
Aug. 8	E	8 50,70	6 23,9	26,80	25,04	28,9	65,2	65,5

Observed Zenith Distances of 22 τ Herculis.

Point on the Limb, 6° 40′ South.

July 29	E	3 56,30	3 57,9	6 40 0 1,60	6 39 59,40	28,8	60,7	61,5
30	W	8 8,81	7 58,6	9,21	50,77	28,8	62,5	60,0
Aug. 1	W	8 5,20	7 53,1	11,10	48,88	29,2	67,0	67,0
7	W	10 1,73	9 50,5	10,23	49,75	28,9	71,0	69,0
12	W	10 16,30	10 4,0	12,50	47,48	29,2	65,2	63,3
13	E	8 12,30	8 16,8	4,50	55,49	29,3	67,3	66,5

Observed Zenith Distances of α Persei.

Point on the Limb, 4° 20′ South.

Aug. 8	W	9 7,66	7 45,7	4 20 1 20,96	4 18 39,91	28,9	66,5	63,0
10	W	8 38,84	7 18,0	20,84	40,03	28,9	70,2	71,0
13	E	10 27,76	11 45,6	17,84	43,03	29,3	57,0	54,0
18	E	8 26,58	9 43,5	16,92	43,95	29,0	60,2	60,2
19	W	8 11,42	6 47,5	22,92	37,94	28,8	60,5	60,3

Observed Zenith Distances of Capella.

Point on the Limb, 7° 40′ South.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div	° ′ rev. div.	° ′ ″	Inches.	°	°
Aug. 7	W	9 7,20	9 36,0	7 40 0 28,80	7 40 22,85	28,7	66,0	66,0
8	E	9 5,23	8. 25,7	38,53	38,59	28,9	71,5	71,0
9	E	6 28,62	5 48,0	39,62	39 68	28,9	81,5	74,5
18	W	9 1,45	9 26,9	25,45	25 49	29,0	74,0	68,0
19	E	8 3,80	7 28,0	34,80	34,86	28,8	68,7	67,5

Operations at the new Station on Arbury Hill, near Daventry, with the Zenith Sector, in the Months of September and October, 1802.

In the Phil. Trans. for 1800, page 658, it will be seen, that the bearing of the Summer House on Bardon Hill, in the north of Leicestershire, from the meridian of Arbury Hill, is 7° 37′ 31″ NW; and, as this spot is only 2776 feet westward from the meridian of Dunnose itself, it follows, that 7° 37′ 31″ may be taken for the bearing of the above object from Arbury Hill. To avoid, however, the possibility of any error arising from adopting this supposition, the direction of the meridian was ascertained, (before the zenith sector was got up,) by a double azimuth of the pole star. From this it appeared, that the angular point of the roof of a house about seven miles distant, was within a few seconds of the true northern direction; and also, that Bardon Hill (the summer house) was 7° 37′ 35″ north-west. By observing these two objects, as the weather suited, the sector was afterwards got into the plane of the meridian.

Observations made on Arbury Hill, to determine the Zenith Distance of β Draconis.

Point on the Limb, 0° 15′ North.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
Sept. 8	W	9 48,90	10 54,7	0 15 1 5,80	0 13 55,09	28,2	51,0	54,0
18	E	9 37,98	8 26,5	11,48	49,40	28.8	70,5	72,5
19	W	9 17,78	10 23,0	5,22	55,67	28,8	71,5	76,5
20	E	9 16,33	8 6,5	9,83	51,06	28,8	68,2	69,0
22	E	9 26,17	8 16,0	10,17	50,71	28,8	79,3	75,3
23	W	8 21,00	9 25,0	4,00	56,89	28,9	70,5	76,5
24	E	9 7,68	7 57,0	9,68	51,21	28,9	71,0	70,5
25	W	9 29,13	10 34,0	4,87	56,02	29.1	74,5	75,5
26	E	9 4,27	7 51,8	11,47	49,41	29,0	64,5	66,5
28	W	10 43,25	11 48,7	5,45	55,45	29,0	65,5	65,5
29	E	9 27,65	8 17,3	10,35	50,53	29,1	79,0	77,5
30	W	9 25,82	10 30,7	4,88	56,04	29,0	64,0	69,5
Oct. 1	E	9 43,20	8 31,0	12,20	48,79	29,0	72,2	71,5
3	W	9 19,02	10 26,6	7,58	53,31	28,7	74,0	73,0

Observed Zenith Distances of γ Draconis.

Point on the Limb, 0° 40′ South.

Sept. 10	W	8 53,85	11 6,4	0 40 2 11,55	0 42 9,76	28,2	51,5	54,0
11	E	8 47,75	6 31,9	15,85	14,07	28,53	48,2	55,0
18	E	9 46,65	7 28,7	17,95	16,17	28,8	70,3	72,3
19	W	9 18,90	11 31,5	12,60	10,82	28,8	67,5	73,5
20	E	9 1,78	6 42,8	17,98	16,20	28,8	68,3	71,4
22	E	9 16,52	6 58,2	17,32	15,54	28,8	79,8	75,8
23	W	8 9,97	10 20,5	10,53	8,74	28,8	67,5	65,3
24	E	9 16,97	7 0,8	16,17	14,39	28,9	70,5	70,2
25	W	9 16,00	11 27,6	11,60	9,81	29,1	74,0	75,2
26	W	9 10,47	11 23,0	12,53	10,75	29,0	59,5	64,2
29	E	9 17,50	7 0,8	16,70	14,92	29,1	64,0	69,5
30	W	9 21,63	11 33,5	11,87	10,08	29,9	64,0	69,5
Oct. 1	E	9 34,95	7 15,5	19,45	17,87	28,9	72,5	71,9
2	E	9 25,33	7 7,0	18,33	16,57	28,8	71,0	75,0
3	W	8 54,30	11 7,1	11,80	10,01	28,6	74,0	73,0

Observed Zenith Distances of 45 d Draconis.

Point on the Limb, 4° 40′ North.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Thermometer. Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
Sept. 8	W	9 57,57	9 21,1	4 40 0 36,47	4 40 38,53	28,2	52,0	54,0
15	W	7 29,48	6 47,3	40,98	41,05	28,9	63,5	66,0
18	E	9 45,55	10 18,6	32,05	32,10	28,8	64,2	67,2
19	W	9 28,10	8 46,6	40,50	40,57	28,8	66,5	72,5
20	E	8 56,23	9 29,1	31,87	31,92	28,8	66,5	69,5
23	W	8 0,83	7 22,4	37,43	37,49	28,8	67,5	65,5
24	E	9 18,78	9 50,4	31,62	31,67	28,9	65,5	63,5
25	W	9 36,25	8 57,1	38,15	38,21	29,0	65,3	67,3
26	E	9 14,12	9 46,5	32,37	32,42	29,0	64,8	66,5
28	E	9 18,62	9 50,0	31,38	31,43	29,0	65,3	64,5
29	W	8 57,55	8 20,0	37,55	37,61	29,1	64,5	69,0
30	W	8 51,62	8 13,5	37,12	38,18	29,0	64,3	69,8
Oct. 1	E	9 25,05	14 58,7	33,65	29,20	28,9	72,0	71,5
2	E	9 18,35	9 50,6	32,35	32,40	28,8	72,5	75,5

Observed Zenith Distances of 46 c Draconis.

Point on the Limb, 3° 5′ North.

Sept. 7	E	9 3,63	11 19,23	3 5 2 15,40	3 7 13,62	28,5	63,0	64,5
10	E	9 3,73	11 19,4	15,67	13,89	28,2	51,0	54,0
15	W	7 30,08	5 6,5	23,58	21,85	28,9	63,5	66,0
16	W	10 22,70	7 55,9	24,80	23,04	29,0	61,5	65,5
18	E	9 29,12	11 47,0	17,88	16,11	28,8	64,0	67,0
19	W	9 40,57	7 16,3	24,27	22,51	28,8	66,5	72,0
20	E	8 34,27	10 52,3	18,03	16,26	28,8	66,0	69,0
21	W	9 55,90	7 29,0	26,90	25,14	28,8	66,5	69,5
22	E	8 2,67	11 20,4	17,73	15,95	28,8	79,2	75,3
23	W	9 20,01	6 45,0	24,10	22,34	28,8	67,5	65,0
24	E	9 3,97	11 22,3	18,33	16,56	28,8	65,5	63,0
25	W	9 42,55	7 19,2	23,35	21,58	29,0	65,5	67,3
26	E	9 9,10	11 27,0	17,90	16,12	29,0	64,5	66,5
28	E	9 17,52	11 35,0	17,48	15,70	29,0	65,5	64,5
29	W	9 13,00	7 48,4	23,60	21,83	29,0	64,5	69,0
30	W	9 4,20	6 38,8	24,40	22,64	29,1	64,5	69,5
Oct. 1	E	9 18,65	11 36,1	17,45	15,67	29,0	68,2	61,4
2	E	9 22,35	14 41,1	18,75	16,97	28,8	68,0	70,5

Observed Zenith Distances of 1 α *Cygni.*

Point on the Limb, 0° 45′ *North.*

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Thermometer. Below.
		rev div.	rev. div.	° ′ rev. div.	° ′ ″	Inches	°	°
Sept. 7	E	8 12,72	10 25,2	0 45 2 12,48	0 47 10,69	28,2	51,0	54,0
8	W	6 54,92	4 36,0	18,92	17,15	28,2	51,5	54,5
15	W	8 52,42	6 31,5	20,92	19,15	28,9	62,5	65,3
16	W	10 31,57	8 9,0	22,57	20,80	28,9	61,0	65,0
18	E	8 21,80	10 38,0	16,20	14,42	28,8	64,3	67,5
19	W	9 37,03	7 14,5	22,53	20,77	28,8	66,5	72,0
20	E	8 24,05	15 43,6	40 7 19,55	13,27	28,8	65,0	67,0
22	E	8 50,82	11 9,0	45 2 17,18	15,40	28,8	66,3	66,5
23	W	8 56,10	6 33,5	22,60	20,83	28,8	67,5	65,3
24	E	8 32,52	10 48,5	15,98	14,20	28,9	59,3	63,5
25	W	9 44,57	7 23,5	21,07	19,30	29,0	66,5	67,0
26	E	9 20,58	11 36,0	15,42	13,64	29,0	64,5	66,5
28	E	9 31,90	11 47,7	15,80	14,02	29,0	60,5	62,5
29	W	9 58,00	7 35,0	23,00	21,23	29,0	64,5	68,0
30	W	9 48,10	7 24,9	23,20	21,43	29,0	62,0	65,5
Oct. 1	E	9 9,42	11 26,0	16,58	14,80	28,9	64,0	66,5
2	E	9 2′,82	11 38,0	16,18	14,40	28,0	65,0	68,0

Observed Zenith Distances of 51 *Draconis.*

Point on the Limb, 0° 50′ *North.*

Sept. 7	E	8 13,88	5 43,5	0 55 2 29,38	0 52 32,37	28,2	51,5	54,5
8	W	6 41,63	4 1,5	0 50 2 49,13	38,39	28,2	51,0	54,0
10	E	9 16,0c	11 53,7	37,70	35,96	28,2	51,0	54,0
16	W	10 39,0c	7 55,5	42,50	40,77	29,0	61,7	65,5
18	E	8 42,0c	11 19,7	36,70	34,96	28,8	64,0	67,2
19	W	9 56,73	7 13,6	43,13	41,42	28,8	66,5	72,0
20	E	8 26,1c	11 13,0	35,90	34,15	28,8	66,5	69,5
22	E	8 54,28	11 31,2	35,92	34,17	28,8	68,5	63,0
23	W	9 4,53	6 21,9	41,63	39,89	28,8	67,5	65,5
25	W	9 34,53	6 51,5	42,03	40,30	29,0	67,0	67,0
26	E	9 24,17	12 1,4	36,23	34,49	29,0	59,5	64,5
28	E	9 30,17	12 7,3	36,13	34,39	29,0	66,0	64,0
29	W	9 17,85	6 53,9	40,95	39,21	29,0	65,5	69,5
30	W	9 35,83	6 51,0	43,83	42,10	29,0	64,0	70,3
Oct. 1	E	9 11,55	11 49,0	37,45	35,71	29,0	68,0	68,0
2	E	9 24,62	11 2,4	36,78	35,04	28,8	68,0	70,5

Observed Zenith Distance of 10 Cygni.

Point on the Limb, 0° 55′ South.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
Sept. 18	E	8 19,17	8 53,6	0 55 0 34,43	0 54 25,51	28,8	64,5	67,5
19	W	9 37,65	9 2,2	35,45	20,49	28,8	66,5	72,0
20	E	8 31,87	9 7,5	34,63	25,31	28,8	65,0	67,0
21	W	10 16,65	9 35,3	40,35	19,58	28,8	65,2	67,2
22	E	8 51,59	9 28,2	35,61	24,33	28,8	66,0	66,0
23	W	8 49,25	8 10,5	38,75	21,19	28,8	65,5	65,5
24	E	8 22,08	8 56,0	33,91	26,02	28,8	59,0	63,0
25	W	9 45,92	9 7,0	38,92	21,02	29,0	66,5	67,0
26	E	9 11,63	9 46,4	34,77	25,17	29,0	59,0	64,0
27	W	8 57,40	8 13,4	44,00	19,93	29,0	52,0	55,5
28	E	8 54,83	9 31,1	35,27	24,67	29,0	60,0	62,0
29	W	9 52,90	9 12,0	40,90	19,03	29,0	64,5	68,0
30	W	9 53,38	9 11,3	42,08	17,85	29,0	62,0	65,0
Oct. 1	E	9 10,95	9 47,0	36,05	23,89	28,9	64,0	66,5
2	E	9 23,18	10 0,3	36,12	23,82	28,8	68,5	65,5

Observed Zenith Distances of γ Ursæ.

Point on the Limb, 2° 35′ North.

Sept. 18	E	9 32,47	8 34,9	2 35 0 56,57	2 34 3,33	28,8	77,5	76,5
23	W	8 20,07	9 20,1	2 35 0 57,03	2,87	28,9	80,0	76,0
26	W	9 22,70	10 18,5	54,80	5,10	29,1	80,5	75,0
Oct. 3	E	9 10,45	8 2,5	1 7,95	33 52,94	28,7	72,8	78,5

Observed Zenith Distances of η Ursæ.

Point on the Limb, 1° 55′ South.

Sept. 10	W	8 16.58	8 24.4	1 55 0 7,82	1 55 7,83	28,1	63,0	64,5
20	E	9 26.02	9 13,9	12,12	12,14	28,8	84,5	80,5
23	W	8 4,60	8 14,1	9,50	9,51	28,9	84,0	82,5
24	E	8 50,25	8 34,5	15,75	15,77	28,9	79,0	75,0
25	W	9 21,40	9 33,5	12,10	12,12	29,0	82,8	80,5
26	E	8 54,63	8 36,0	18,03	18,06	29,1	80,0	77,0
28	E	10 5,25	9 47,7	16,55	16,57	29,1	78,5	72,5
30	W	10 6,12	10 15,0	8,88	8,89	29,1	84,0	76,0
Oct. 3	E	9 27,63	9 9,2	18,43	18,46	29,0	80,0	76,2

Observed Zenith Distances of ζ Ursæ.

Point on the Limb, 3° 45′ North.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
Sept. 24	E	8 40,70	7 44,4	3 45 0 55,60	3 44 4,31	28,9	79,5	75,5
26	W	9 1,95	9 53,5	51,55	8,36	29,1	80,0	77,5
30	E	9 50,72	8 50,0	1 0,72	0,18	29.0	84,0	70,0
Oct. 3	E	7 3,00	6 1,9	1 1,10	43 59,80	28,7	80,5	75,5

Observed Zenith Distances of 22 τ *Herculis.*

Point on the Limb, 5° 15′ South.

Sept. 18	E	9 50,42	8 52,5	5 25 0 56,92	5 25 57,01	28,8	72,5	74,5
Oct. 3	W	9 33,10	10 24,5	50,40	50,48	28,6	76,5	76,0

Observed Zenith Distances of α Persei.

Point on the Limb, 3° 5′ South.

Sept. 8	E	7 35,23	8 0,6	3 5 0 23,37	3 4 36,59	28,8	41,0	44,0
12	E	8 29,27	8 52,5	23,23	36,73	28,8	41,5	44,5
16	W	9 17,50	8 47,9	28,60	31,35	28,9	55,7	57,5
18	W	9 53,52	9 25,3	28,22	31,73	28,8	57,2	58,5
19	E	7 52,87	8 11,0	23,13	36,83	28,8	53,5	58,0
22	E	8 44,73	8 9,3	23,57	36,39	28,8	58,0	62,0
23	W	8 58,60	8 27,4	30,60	29,35	28,7	60,0	60,0
25	E	8 58,42	9 23,7	24,28	35,67	29,0	49,5	53,5
26	W	9 49,10	9 19,8	29,30	30,65	29,1	55,5	54,3

Observed Zenith Distances of Capella.

Point on the Limb, 7° 40′ South.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer.	Thermometer. Above.	Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°	°
Sept. 11	E	9 47,77	8 15,9	6 25 1 33,87	6 26 33,02	28,8	46,5	50,5
12	E	8 45,17	7 12,1	33,07	32,22	28,7	38,5	43,5
14	W	7 41,57	9 9,1	26,53	25,67	28,8	53,5	56,5
16	W	9 51,50	10 20,3	27,80	26,94	28,9	54,5	56,5
18	E	9 24,77	7 48,8	34,97	34,12	28,9	55,0	58,0
19	W	8 10,88	9 38,0	27,52	26,66	28,9	56,0	57,5
20	E	8 48,20	7 15,2	33,00	32,15	28,8	57,2	59,1
21	W	8 16,97	9 45,5	28,53	27,67	28,8	54,0	56,5
22	E	9 6,93	7 34,0	31,93	31,08	28,8	58,0	62,0
23	W	8 48,50	10 16,2	26,70	25,84	28,7	60,5	58,5
25	E	8 53,40	7 20,0	33,30	32,45	29,0	48,5	48,5
26	W	9 49,52	11 18,6	28,08	27,22	29,1	55,0	56,5

Operations at the Royal Observatory with the Zenith Sector.

April, 1802.

Observed Zenith Distances of β Draconis.

Point on the Limb, 0° 55′ North.

April 16	W	9 57,80	6 44,2	0 55 3 13,60	0 58 10,92	29,9	40,0	40,0
23	E	8 35,49	11 40,9	5,41	2,71	30,1	38,0	38,0
25	W	10 7,84	6 53,0	13,84	11,16	29,8	44,0	44,0
26	W	9 24,63	6 11,5	13,13	10,45	29,5	42,0	42,0

Observed Zenith Distances of γ Draconis.

Point on the Limb, 0° 0′ North.

April 16	W	10 21,73	8 18,5	0 0 2 3,23	0 2 1,43	29,9	45,0	
19	W	9 9,40	7 4,1	5,30	3,50	31,1	53	
22	E	8 14,48	10 9,5	1 54,02	1 53,21	29,9	55	
23	E	9 21,79	10 18,5	55,71	54,90	30,1	38	
25	W	9 39,52	7 34,4	2 5,12	2 3,32	29	44	

Observed Zenith Distances of 45 *Draconis.*

Point on the Limb, 5° 20′ *North.*

Day of the month.	Face of the arch. E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance reduced.	Barometer. Above.	Thermometer. Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°
April 19	W	9 38,57	4 46,5	5 20 4 51,07	5 24 47,48	31,1	53
23	E	8 21,37	13 6,0	43,63	40,01	30,1	38
25	W	9 47,20	4 54,5	51,70	48,19	29,8	40

Observed Zenith Distance of 46 *c Draconis.*

Point on the Limb, 3° 50′ *North.*

April 15	W	9 15,70	7 41,9	3 50 1 32,80	3 51 31,95	29,8	44

Observed Zenith Distance of 51 *Draconis.*

Point on the Limb, 1° 36′ *North.*

April 19	W	9 48,80	8 55,7	1 35 0 52,10	1 35 52,19	31,1	53
23	E	8 43,56	10 27,8	43,34	43,31	30,1	38
25	W	8 54,53	7 46,0	49,83	49,91	29,8	44

Observed Zenith Distance of 1 *κ Cygni.*

Point on the Limb, 1° 30′ *North.*

April 23	E	9 20,36	10 42,8	1 30 1 22,44	1 31 21,53	30,1	38
25	W	8 29,76	6 58,6	30,16	29,31	29,5	51

Observed Zenith Distance of 10 *ι Cygni.*

Point on the Limb, 0° 10′ *South.*

April 19	W	11 32,42	11 42,6	0 10 0 10,18	0 10 10,19		
23	E	9 36,12		18,42	18,45		

Observed Zenith Distance of γ Ursæ.

Point on the Limb, 3° 15′ North.

Day of the month.	Face of the arch, E. or W.	Plumb-line.	Observation of the star.	Zenith distance in revolutions and parts.	Zenith distance rectified.	Barometer. Above.	Thermometer. Below.
		rev. div.	rev. div.	° ′ rev. div.	° ′ ″	Inches.	°
April 20	E	8 44,30	12 42,7	3 15 3 58,40	3 18 55,79	29,9	50
22	E	10 36,00	14 36,0	4 0,00	56,39	29,9	50
23	E	4 28,25	8 29,5	0,75	57,14	30,1	48
24	W	9 36,90	5 25,1	11,80	19 8,21	29,8	47

Observed Zenith Distance of η Ursæ.

Point on the Limb, 1° 10′ South.

April 16	W	10 13,90	10 40,7	1 10 0 26,80	1 10 26,84	29,9	45
23	E	3 37,50	3 4,6	32,40	32,45	30,1	38

Observed Zenith Distance of 85 ι Herculis.

Point on the Limb, 5° 20′ South.

April 16	W	11 1,59	11 47,9	5 20 0 46,31	5 20 46,39	29,0	40
19	W	9 40,30	10 30,5	39,26	39,26	31,5	53
23	E	9 21,16	9 23,5	56,66	56,75	30,1	38

Table showing the Runs of the Micrometer-screw over every 5′ in the first Degree on each Side of Zero.

	Right Hand Arc.							*Left Hand Arc.*						
	°	′	R.	D.	R.	D.		°	′	R	D.	R	D.	
At	0	0	8	55.43				At 0	0	9	16,31			
	0	5	14	0,88	—	5	4,45	0	5	4	11,77	—	5	4,54
	0	5	9	32,55				0	5	9	8,73			
	0	10	14	37,10	—	5	4,55	0	10	4	4,17	—	5	4,56
	0	10	9	40,03				0	10	8	53,67			
	0	15	14	44,37	—	5	4,34	0	15	3	49,17	—	5	4,50
	0	15	9	19,13				0	15	9	16,13			
	0	20	14	23,58	—	5	4,45	0	20	4	11,69	—	5	4,44
	0	20	9	54,07				0	20	9	17,50			
	0	25	14	58,47	—	5	4,40	0	25	4	12,97	—	5	4,53
	0	25	9	39,23				0	25	10	4,30			
	0	30	14	43,64	—	5	4,41	0	30	4	58,80	—	5	4,50
	0	30	9	25,77				0	30	8	52,0			
	0	35	14	30,21	—	5	4,44	0	35	3	47,53	—	5	4,47
	0	35	9	58,53				0	35	9	7,83			
	0	40	15	4,07	—	5	4,54	0	40	4	3,30	—	5	4,53
	0	40	9	0,53				0	40	9	3,31			
	0	45	14	5,07	—	5	4,54	0	45	3	57,90	—	5	4,41
	0	45	9	12,47				0	45	9	12,03			
	0	50	14	17,02	—	5	4,55	0	50	4	8,23	—	5	4,40
	0	50	9	43,07				0	50	9	4,50			
	0	55	14	47,50	—	5	4,43	0	55	4	0,03	—	5	4,47
	0	55	8	41,27				0	55	8	35,0			
	1	0	13	45,77	—	5	4,50	1	0	3	30,43	—	5	4,57

Table for converting the Divisions shewn on the Micrometer Head into Seconds; the Space subtended by 5′ on the Limb being found = 5 Revolutions 45 Divisions, as deduced from the Measurement of the Total Arches.

R.	D.	″	R.	D.	″
0	1	1,002	0	30	30,050
0	2	2,003	0	31	31,052
0	3	3,005	0	32	32,053
0	4	4,007	0	33	33,055
0	5	5,008	0	34	34,057
0	6	6,010	0	35	35,058
0	7	7,012	0	36	36,060
0	8	8,013	0	37	37,062
0	9	9,015	0	38	38,063
0	10	10,016	0	39	39,065
0	11	11,018	0	40	40,067
0	12	12,020	0	41	41,068
0	13	13,022	0	42	42,170
0	14	14,023	0	43	43,072
0	15	15,025	0	44	44,073
0	16	16,027	0	45	45,075
0	17	17,028	0	46	46,077
0	18	18,030	0	47	47,078
0	19	19,032	0	48	48,080
0	20	20,033	0	49	49,082
0	21	21,035	0	50	50,083
0	22	22,037	0	51	51,085
0	23	23,038	0	52	52,087
0	24	24,040	0	53	53,088
0	25	25,042	0	54	54,090
0	26	26,043	0	55	55,092
0	27	27,045	0	56	56,093
0	28	28,047	0	57	57,095
0	29	29,048	0	58	58,097

Table for supplying the necessary Correction to the observed Zenith Distance of a Star, on account of the Expansion or Contraction of the sectorial Tube by 1° of Heat.

Zenith distance observed.	Correction for 1° of heat.	Zenith distance observed.	Correction for 1° of heat.
° ′	″	° ′	″
1 —	0,018	4 30 —	0,084
1 30 —	0,028	5 —	0,093
2 —	0,037	5 30 —	0,102
2 30 —	0,046	6 —	0,111
3 —	0,056	6 30 —	0,121
3 30 —	0,065	7 —	0,130
4 —	0,074	7 30 —	0,129

In using the above Table, the corrections are to be taken as negative, if the upper thermometer denotes the air to be hotter towards the top of the observatory than round the limb of the sector; and positive, if the reverse.

Reduction of the several Observations contained in the preceding Article, from the respective Days on which they were made, to the first of January, 1802; the Equations being those for Aberration, Nutation, semi-annual solar Equation, Precession, and Refraction; with the Zenith Distances of the several Stars deduced therefrom.

Reduction of the Observations made at Dunnose.

β Draconis, N.

Face of limb, West.		Face of limb, East.			
May 11—1° 50′	7″,65	May 13—1° 50′	0″,23	Zenith dist. 1° 50′ 3″,46	
14	7,0	16	1,10	+1,83	Mean refraction.
June 5	6,11	June 8	0,12	−0,05	Temperature.
				+0,00	Expansion of axis.
11	6,99	13	0,55	Mean zen. dist. 1 50	5,24.
14	5,87	16	0,01	Line of collimation	3,42.
17	6,32	18	49 58,59		
20	7,43	21	0,68		
Mean 1 50	6,88	Mean 1 50	0,04		

γ Draconis, N.

May 11—0° 54′	0″,34	May 10—0° 53′	51″,66	Zenith dist.	0° 53′ 55″,75
14	0,12	13	52,31	+ 0,91	Refraction.
June 11	53 59,45	16	51,54	− 0,02	Temperature.
				− 0,01	Expansion of axis.
14	59,14	June 13	51,53	Mean zen. dist. 0 53	56,63.
17	59,44	17	53,58	Line of collimation	3,64.
20	57,83	18	51,11		
		21	53,07		
Mean 0 53	59,39	Mean 0 53	52,11		

45 d Draconis, N.

June 14—6° 16′	45″,24	June 13—6° 16′	36″,66	Zenith dist.	6° 16′ 41″,70
18	47,41	16	37,91	+ 6,29	Refraction.
21	45,99	20	37,47	− 0,21	Temperature.
				− 0,12	Expansion of axis.
Mean 6 16	46,21	Mean 6 16	37,29	Mean zen. dist. 6 16	47,66.
				Line of collimation	4,46.

46 c Draconis, N.

June 14—4° 43′	29″,43	June 13—4° 43′	20″,76	Zenith dist.	4° 43′ 24″,42+4″,71 (refr. &c.)=4° 43′ 28″,93.
18	26,06	16	19,99	Line of collimation	3,41.
21	28,09	28	22,18		
Mean 4 43	27,86	Mean 4 43	20,98		

51 *Draconis, N.*

Face of limb, West.	Face of limb, East.	
June 14—2° 28′ 45″,62	June 13—2° 28′ 38″,26	Zenith dist. 2° 28′ 41″,71+2″,34 (refr. &c.)=2° 28′ 44″,05.
18 44,85	10 37,67	Line of collimation 3,40.
21 44,85	20 39,01	
Mean 2 28 45,11	Mean 2 28 38,31	

μ *Draconis, N.*

May 11—4° 7′ 1″,57	May 13—4° 6′ 51″,29	Zenith dist. 4° 6′ 55″,30+4″, (refr. &c.)=4° 6′ 59″,30.
14 6 57,63	June 8 51,58	Line of collimation 3,68.
June 14 59,13	13 51,00	
17 58,18	16 51,12	
20 58,43	18 52,20	
	21 52,57	
Mean 4 6 58,99	Mean 4 6 51,62	

16 *Draconis, N.*

May 11—2° 42′ 34″,99	June 13—2° 42′ 26″,55	Zenith dist. 2° 42′ 30″,63+2″,63 (refr. &c.)=2° 42′ 33″,26.
14 34,17	16 27,73	Line of collimation 3,58.
16 33,27	18 26,85	
June 11 34,25		
14 34,26		
20 34,31		
Mean 2 42 34,21	Mean 2 42 27,04	

1 κ *Cygni, N.*

June 14—2° 23′ 26″,44	June 13—2° 23′ 16″,46	Zenith dist. 2° 23′ 20″,58+2″,28 (refr. &c.)=2° 23′ 22″,86.
18 23,20	16 16,54	Line of collimation 3,80.
21 20,51	20 17,31	
Mean 2 23 24,38	Mean 2 23 16,77	

10 ι *Cygni, N.*

June 14—0° 41′ 43″,52	June 13—0° 41′ 35″,84	Zenith dist. 0° 41′ 40″,08+0″,68 (refr. &c.)=0° 41′ 40″,68
18 43,53	16 36,42	Line of collimation 3,15.
21 42,69	20 38,54	
Mean 0 41 43,24	Mean 0 41 36,93	

γ *Ursæ, N.*

May 11—4° 10′ 33″,47	May 9—4° 10′ 28″,18	Zenith dist 4° 10′ 32″,46+3″,77 (refr. &c.)=4° 10′ 36″,23.
15 30,73	10 28,58	Line of collimation 3,02.
June 5 36,65	13 29,82	
13 35,75	14 29,02	
14 34,80	17 30,01	
	20 29,42	
	June 8 30,24	
	16 30,24	
Mean 4 10 35,48	Mean 4 10 29,44	

η *Ursæ, S.*

Face of limb, West.	Face of limb, East.	
May 14—0° 18′ 38″,84	May 10—0° 18′ 44″,08	Zenith dist. 0° 18′ 42″,61+0″,32 (refr. &c.)=0° 18′ 42″,93.
16 40,16	13 45,86	Line of collimation 3,06.
June 5 39,64	15 46,11	
11 37,13	17 45,01	
13 38,62	June 8 47,04	
16 42,06	12 46,57	
18 39,89	14 45,21	
	20 46,18	
	21 43,78	
Mean 0 18 39,48	Mean 0 18 45,54	

ζ *Ursæ, N.*

May 11—5° 20′ 34″,10	May 13—5° 20′ 26″,41	Zenith dist. 5° 20′ 30″,53+5″,13 (refr. &c.)=5° 20′ 35″,66.
June 5 34,15	17 28,46	Line of collimation 3,76.
11 34,42	June 8 25,28	
18 34,57	14 26,96	
	17 26,38	
	20 27,14	
Mean 5 20 34,30	Mean 5 20 26,77	

85 *Herculis, S.*

May 14—4° 29′ 54″,76	May 10—4° 30′ 0″,16	Zenith dist. 4° 29′ 57″,48+4″,47 (refr. &c.)=4° 30′ 1″,95.
June 14 53,20	13 1,39	Line of collimation 3,46.
	16 1,18	
Mean 4 29 53,98	Mean 4 30 0,91	

υ *Herculis, S.*

May 14—4° 1′ 25″,29	May 13—4° 1′ 33″,50	Zenith dist. 4° 1′ 29″,55+3″,69 (refr. &c.)=4° 1′ 33″,24.
16 26,46	June 13 32,52	Line of collimation 3,35.
June 5 26,51	16 32,56	
14 26,51	18 32,56	
	20 33,46	
Mean 4 1 26,19	Mean 4 1 32,90	

52 *Herculis, S.*

May 14—4° 16′ 53″,72	May 13—4° 17′ 0″,15	Zenith dist. 4° 16′ 57″,08+4″,20 (refr. &c.)=4° 17′ 1″,28.
June 11 53,23	16 0,34	Line of collimation 3,76.
14 52,63	June 8 0,60	
17 54,90	13 0,63	
20 54,02	16 0,60	
	21 0,51	
Mean 4 16 53,70	Mean 4 17 0,47	

22 τ *Herculis,*

Face of limb, West.		Face of limb, East.	
May 11	3° 49′ 30″,31	May 10	3° 49′ 38″,10
14	29,26	13	37,23
16	30,63	June 8	35,04
June 5	29,92	13	35,88
11	29,43	18	35,86
14	30,09	21	36,83
17	29,86		
20	31,58		
Mean	3 49 30,16	Mean	3 49 36,49

Zenith dist. 3° 49′ 33″,32 + 3″,78 (refr. &c.) = 3° 49′ 37″,10.
Line of collimation 3,16.

Capella, S.

May 12	4° 50′ 55″,46	May 11	4° 50′ 2,″79
15	54,02	13	1,47
June 8	54,87	June 11	2,0
15	55,87	16	2,26
21	56,91		
22	55,24		
Mean	4 50 55,49	Mean	4° 50 2,13

Zenith dist. 4° 59′ 58″,81 + 4″,07 (refr. &c.) = 4° 50′ 2″,88.
Line of collimation 3,31.

Reduction of the Observations made at Clifton, (the northern Extremity of the meridional Arc,) and the Zenith Distances of the several Stars deduced therefrom.

β *Draconis, S.*

July 20	1° 0′ 13″,82	July 26	1° 0′ 22″,41
22	13,15	29	20,26
28	12,38	Aug. 1	20,39
31	12,15	5	20,16
Aug. 3	13,29	8	20,15
7	12,87	12	21,25
3	13,42	17	20,11
18	13,80		
Mean	1 0 13,11	Mean	1 0 20,68

Zenith dist. 1° 0′ 16″,89 + 0″,95 (refr. &c.) = 1° 0′ 17″,84.
Line of collimation 3,78.

γ *Draconis, S.*

July 20	1° 56′ 21″,63		1° 56′ 28″,50
22	21,47		27,14
26	21,72		27,15
29	21,67		28,86
Aug. 1	22,90		28,54
11	20,45		28,28
13	21,55		28,66
18	21,03		
Mean	1 56 21,56	Mean	1 56 28,16

Zenith dist. 1° 56′ 24″,86 + 1″,78 (refr. &c.) = 1° 56′ 26″,64.
Line of collimation 3,30.

45 *d Draconis, N.*

Face of limb, West.		Face of limb, East.		
July 22	3° 26′ 23″,96	July 31	3° 26′ 16″,41	Zenith dist. 3° 26′ 19″,63+3″,29 (refr. &c.)=3° 26′ 22″,92.
26	22,92	Aug. 12	15,23	Line of collimation 3,72.
29	23,35	17	16,09	
Aug. 7	23,0			
13	23,7			
18	23,26			
Mean	3 26 23,36	Mean	3 26 15,91	

46 *c Draconis, N.*

July 20	1° 53′ 7″,60	July 28	1° 53′ 1″,11	Zenith dist. 1° 53′ 4″,44+1″,80 (refr. &c.)=1° 53′ 6″,24.
22	8,01	31	52 59,97	Line of collimation 3,47.
Aug. 7	7,77	Aug. 3	53 1,99	
13	8,20	5	0,59	
18	8,04	12	1,34	
		17	0,84	
Mean	1 53 7,92	Mean	1 53 0,97	

51 *Draconis, S.*

Aug. 7	0° 21′ 33″,26	July 28	0° 21′ 41″,62	Zenith dist. 0° 21′ 37″,78+0″,34 (refr. &c.)=0° 21′ 38″,12.
9	33,99	31	42,87	Line of collimation 4,15.
13	33,83	Aug. 5	42,16	
18	33,45	12	41,30	
		17	41,68	
Mean	0 21 33,63	Mean	0 21 41,93	

μ Draconis, N.

July 20	1° 16′ 39″,87	July 29	1° 16′ 34″,53	Zenith dist. 1° 16′ 36″,97+1″,23 (refr. &c.)=1° 16′ 38″,20.
28	38,98		32,92	Line of collimation 3,25.
30	40,32			
Aug. 13	41,73			
Mean	1 16 40,22	Mean	1 16 33,72	

16 *Draconis, S.*

July 30	0° 7′ 47″,75	July 29	0° 7′ 54″,09	Zenith dist. 0° 7′ 51″,15+0″,10 (refr. &c.)=0° 7′ 51″,25.
		Aug. 5	0 55,04	Line of collimation 3,40.
		Mean	0 7 54,56	

1 *κ Cygni, S.*

July 20	0° 26′ 55″,72	July 28	0° 27′ 3″,20	Zenith dist. 0° 26′ 59″,91+0″,41 (refr. &c.)=0° 27′ 0″,32.
22	56,66	29	4,99	Line of collimation 3,68.
26	56,97	31	4,36	
29	56,35	Aug. 5	2,56	
30	55,28	12	4,29	
Aug. 7	56,45	17	2,20	
9	56,55			
13	56,36			
18	55,79			
Mean	0 26 56,23	Mean	0 27 3,60	

10 *Cygni, S.*

Face of limb, West.			Face of limb, East.			
July 20	2°	8′ 36″,86	July 28	2°	8′ 42″,47	Zenith dist. 2° 8′ 40″,23 + 1,″99 (refr. &c.) = 2° 8′ 42,″22.
29		35,01	31		44,05	Line of collimation 3,55.
30		36,42	Aug. 5		43,54	
Aug. 1		37,37	12		45,24	
7		37,02	17		43,76	
9		37,56				
18		35,96				
Mean	2	8 36,68	Mean	2	8 43,79	

γ *Ursæ, N.*

Aug. 17—1° 20′ 2,″84.

ζ *Ursæ, N.*

Aug. 5	2°	30′ 10″,72	July 29	2°	30′ 4,″59	Zenith dist. 2° 30′ 8″,18 + 2″,19 (refr. &c.) = 2° 30′ 10″,37.
9		12,38	Aug. 8		4,47	Line of collimation 3,37.
			17		5,39	
Mean	2	30 11,55	Mean	2	30 4,81	

η *Ursæ, S.*

July 23	3°	8′ 59,″78	Aug. 8	3°	9′ 8″,03	Zenith dist. 3° 9′ 4″,26 + 2″,72 (refr. &c.) = 3° 9′ 6″,98.
26		9 0,93	17		7,85	Line of collimation 3,67.
Aug. 4		9 1,07				
Mean	3	9 0,59	Mean	3	9 7,94	

85 *Herculis, S.*

July 20	7°	20′ 14″,13	July 23	7°	20′ 21″,69	Zenith dist. 7° 20′ 18″,08 + 6″,90 (refr. &c.) = 7° 20′ 24″,98.
28		13,19	5		22,57	Line of collimation 4,52.
31		12,93	17		23,59	
Aug. 1		12,86				
7		14,71				
Mean	7	20 13,56	Mean	7	20 22,61	

υ *Herculis, S.*

July 30	6°	51′ 46″,31	July 21	6°	51′ 52″,89	Zenith dist. 6° 51′ 50″,45 + 6″,35 (refr. &c.) = 6° 51′ 56″,80.
			29		56,32	Line of collimation 4,14.
			Mean	6	51 54,60	

52 *Herculis, S.*

July 28	7°	7′ 15″,02	July 29	7°	7′ 22″,76	Zenith dist. 7° 7′ 18″,69 + 6″,76 (refr. &c.) = 7° 7′ 25″,45.
30		14,21	Aug. 8		22,63	Line of collimation 4,04.
Mean	7	7 14,6	Mean	7	7 22,69	

22 τ *Herculis, S.*

July 30	6°	39′ 51″,84	July 29	6°	39′ 55″,11 + 6″,18 (refr. &c.) = 6° 40′ 1″,29.	
Aug. 4		50,64	Aug. 13		39 58,02	Line of collimation 4,16.
7		51,80				
12		49,96				
Mean	6	39 51,06	Mean	6	39 59,17	

α Persei, S.

Face of limb, West.	Face of limb, East.	
Aug. 8—4° 18′ 29″,44	Aug. 13—4° 18′ 33″,15	Zenith dist. 4° 18′ 31″,65 + 4″,37 (refr. &c.) = 4° 18′ 36″,02.
29,78	18 34,76	Line of collimation 2,28.
28,87		
Mean 4 18 29,36	Mean 4 18 33,95	

Capella, S.

Aug. 7—7° 40′ 15″,60	Aug. 8—7° 40′ 25″,30	Zenith dist. 7° 40′ 19″,06 + 6″,60 (refr. &c.) = 7° 40′ 25″,66.
18 11,94	9 26,46	Line of collimation 5,30.
	19 21,32	
Mean 7 40 13,76	Mean 7 40 24,36	

Reduction of the Observations made at Arbury Hill, (the intermediate Point on the meridional Arc,) and the Zenith Distances of the several Stars deduced therefrom.

β Draconis, N.

Sept. 8—0° 13′ 47″,67	Sept. 18—0° 13′ 41″,91	Zenith dist. 0° 13′ 45″,61 + 0″,21 (refr. &c.) = 0° 13′ 45″,82.
19 48,20	20 43,61	Line of collimation 2,71.
23 49,55	22 43,32	
25 48,76	24 43,90	
28 48,38	26 42,24	
30 49,10	29 43,54	
Oct. 3 46,63	Oct. 1 41,94	
Mean 0 13 48,33	Mean 0 13 42,92	

γ Draconis, S.

Sept. 10—0° 42′ 18″,72	Sept. 11—0° 42′ 23″,08	Zenith dist. 0° 42′ 22″,08 + 0″,65 (refr. &c.) = 0° 42′ 22″,73.
19 20,01	18 25,43	Line of collimation 2,92.
23 18,03	20 25,49	
25 19,07	22 24,84	
26 20,07	24 24,67	
30 19,21	29 24,08	
Oct. 3 18,98	Oct. 1 26,95	
	2 25,56	
Mean 0 42 19,16	Mean 0 42 25,01	

45 d Draconis, S.

Sept. 8—4° 40′ 25″,36	Sept. 18—4° 40′ 19″,99	Zenith dist. 4° 40′ 22″,80 + 4″,41 (refr. &c.) = 4° 40′ 27″,21.
15 29,16	20 19,65	Line of collimation 3,65.
19 28,37	24 19,22	
23 25,07	26 19,87	
25 25,57	28 18,86	
29 25,03	Oct. 1 16,57	
30 25,57	2 19,89	
Mean 4 40 26,45	Mean 4 40 19,15	

46 *c Draconis, N.*

Face of limb, West.		Face of limb, East.		
Sept. 15—3°	7′ 9″,56	Sept. 7—3°	7′ 2″,31	Zenith dist. 3° 7′ 6″,25+3″,05 (refr. &c.)=3° 7′ 9″,30.
16	10,67	10	2,19	Line of collimation 3,21.
19	9,89	18	3,58	
21	9,38	20	3,58	
23	9,46	22	3,13	
25	8,62	24	3,62	
29	8,70	26	3,10	
30	9,49	28	2,61	
		Oct. 1	2,51	
		2	3,79	
Mean 3	7 9,47	Mean 3	7 3,04	

51 *Draconis, N.*

Sept. 8—0°	52′ 26″,01	Sept. 7—0°	52′ 20″,13	Zenith dist. 0° 52′ 23″,57+0″,85 (refr. &c.)=0° 52′ 24″,42.
16	27,89	10	23,30	Line of collimation 2,89.
19	27,60	18	21,23	
23	25,70	20	20,26	
25	25,98	22	20,06	
29	24,59	26	20,05	
30	27,43	28	19,87	
		Oct. 1	21,01	
		2	20,31	
Mean 0	52 26,46	Mean 0	52 20,68	

1 *ϰ Cygni, N.*

Sept. 8—0°	47′ 4″,07	Sept. 7—0°	46′ 57″,79	Zenith dist. 0° 47′ 2″,16+0″,76 (refr. &c.)=0° 47′ 2″,92.
15	5,02	18	59,88	Line of collimation 3,22.
16	6,59	20	58,5	
18	6,13	22	47 0,44	
23	5,77	24	46 59,04	
25	4,06	26	58,30	
29	5,67	28	58,56	
30	5,82	Oct. 1	59,13	
		2	58,79	
Mean 0	47 5,39	Mean 0	46 58,94	

10 *ι Cygni.*

Sept. 19—0°	54′ 35″,59	Sept. 18—0°	54′ 40″,47	Zenith dist. 0° 54′ 38″,21+0″,88 (refr. &c.)=0° 54′ 39″,09.
21	34,94	20	40,42	Line of collimation 2,48.
23	36,74	22	39,82	
25	36,83	24	41,72	
27	35,86	26	41,11	
29	35,23	28	40,78	
30	34,11	1	40,14	
		2	40,24	
Mean 0	54 35,62	Mean 0	54 40,59	

γ Ursæ, N.

Face of limb, West.		Face of limb, East.		
Sept. 23	2° 34′ 12″,07	Sept. 18	2° 34′ 5″,73	Zenith dist. 2° 34′ 9″,59 + 2″,29 (refr. &c.) = 2° 34′ 11″,88.
26	15,28		5,29	Line of collimation 4,08.
Mean	2 34 13,67	Mean	2 34 5,51	

η Ursæ, S.

Sept. 10	1° 55′ 1″,14	Sept. 20	1° 55′ 4″,41	Zenith dist. 1° 55′ 3″,03 + 1″,65 (refr. &c.) = 1° 55′ 4″,68.
23	54 59,80	24	4,84	Line of collimation 2,79.
25	55 2,57	26	7,75	
30	54 57,42	28	5,68	
		Oct. 3	6,41	
Mean	1 55 0,23	Mean	1 55 5,82	

ζ Ursæ, N.

Sept. 26	3° 44′ 11″,63	Sept. 24	3° 44′ 6″,99	Zenith dist. 3° 44′ 8″,63 + 3″,73 (refr. &c.) = 3° 44′ 12″,36.
		30	4,67	Line of collimation 3,0.
		Oct. 3	5,28	
		Mean	3 44 5,64	

22 τ Herculis, S.

Sept. 3	5° 25′ 50″,78	Sept. 18	5° 25′ 58″,80	Zenith dist. 5° 25′ 54″,79 + 5″,03 (refr. &c.) = 5° 25′ 59″,82.
				Line of collimation 4,01.

α Persei, S.

Sept. 16	3° 4′ 26″,57	Sept. 8	3° 4′ 30″,66	Zenith dist. 3° 4′ 29″,53 + 3″,07 (refr. &c.) = 3° 4′ 32″,60.
18	27,69	12	31,49	Line of collimation 2,63.
23	26,22	19	32,95	
26	27,10	22	32,91	
		25	32,91	
Mean	3 4 26,89	Mean	3 40 32,18	

Capella, S.

Sept. 14	6° 26′ 12″,39	Sept. 11	6° 26′ 19″,64	Zenith dist. 6° 26′ 16″,46 + 6″,44 (refr. &c.) = 6° 26′ 22″,90.
16	13,75	12	18,89	Line of collimation 2,89.
19	13,59	18	21,00	
21	14,68	20	19,10	
23	12,93	22	18,03	
26	14,48	25	19,64	
Mean	6 26 13,61	Mean	6 26 19,39	

Reduction of the Observations made at the Royal Observatory, and the Zenith Distances of the several Stars deduced therefrom.

β Draconis, N.

April 16	0° 58′ 37″,66	April 23	0° 58′ 28″,07	Zenith dist. 0° 58′ 32″,14 + 0″,99 (refr. &c.) = 0° 58′ 33″,13.
25	36,02			Line of collimation 4,07.
26	34,98			
Mean	0 58 36,22			

γ *Draconis, N.*

Face of limb, West.	Face of limb, East.	
April 16—0° 2′ 28″,37	April 22—0° 2′ 19″,05	Zenith dist. 0° 2′ 24″,364 + 0″,03 (refr. &c.) = 0° 2′ 24″,39.
19 29,92	23 20,54	Line of collimation 4,57.
25 28,55		
Mean 0 2 28,94	Mean 0 2 19,79	

45 *d Draconis, N.*

April 19—5° 25′ 14″,51	April 23—5° 25′ 6″,17	Zenith dist. 5° 25′ 10″,22 + 5″,59 (refr. &c.) = 5° 25′ 15″,81.
25 14,03		Line of collimation 4,05.
Mean 5 25 14,27		

46 *c Draconis, N.*

April 25—3° 51′ 57″,64.

51 *Draconis, N.*

April 19—1° 37′ 18″,23	April 23—1° 37′ 8″,79	Zenith dist. 1° 37′ 12″,61 + 1″,54 (refr. &c.) = 1° 37′ 14″,15.
25 14,62		Line of collimation 3,81.
Mean 1 37 16,42		

1 *κ Cygni.*

April 25—1° 31′ 54″,14	April 23—1° 31′ 46″,65	Zenith dist. 1° 31′ 50″,39 + 1″,48 (refr. &c.) = 1° 31′ 51″,87.
		Line of collimation 3,74.

10 *ι Cygni.*

April 19—0° 9′ 45″,02	April 23—0° 9′ 53″,90	Zenith dist. 0° 9′ 49″,41 + 0″,20 (refr. &c.) = 0° 9′ 49″,60.
		Line of collimation 4,44.

γ *Ursæ.*

April 24—3° 19′ 7″,08	April 21—3° 18′ 55″,69	Zenith dist. 3° 19′ 1″,43 + 3″,24 (refr. &c.) = 3° 19′ 4″,67.
	22 55,55	Line of collimation 5,65.
	23 56,12	
	Mean 3 18 55,78	

η *Ursæ.*

April 16—1° 10′ 10″,19	April 23—1° 10′ 17″,60	Zenith dist. 1° 10′ 13″,85 + 1″,22 (refr. &c.) = 1° 10′ 15″,07.
		Line of collimation 3,70.

85 *ι Herculis.*

April 16—5° 20′ 20″,47	April 23—5° 20′ 32″,04	Zenith dist. 5° 20′ 25″,10 + 5″,61 (refr. &c.) = 5° 20′ 30″,77.
19 15,87		Line of collimation 6,93.
Mean 5 20 18,17		

Capella.

April 13—5° 41′ 21″,09	April 24—5° 41′ 30″,91	Zenith dist. 5° 41′ 26″,42 + 5″,79 (refr. &c.) = 5° 41′ 32″,21.
21 22,74		Line of collimation 4,5.
Mean 5 41 21,91		

Previous to my entering on the following article, it may not be improper to exhibit, under their proper points of view, the several quantities derived from observation, expressive of the differences of the zenith distances, or the deviation of the point of intersection of the meridional and horizontal wires from the true line of collimation.

At Dunnose.

		n
β	Draconis	3,42
γ	———	3,64
45 d	———	4,46
46 c	———	3,41
51	———	3,40
μ	———	3,68
16	———	3,58
1 $\varkappa$	Cygni	3,80
10 ι	———	3,15
γ	Ursæ	3,02
η	———	3,06
ζ	———	3,76
85 i	Herculis	3,46
υ	———	3,35
52	———	3,76
22 τ	———	3,16
	Capella	3,31

At Clifton.

β	Draconis	3,78
γ	———	3,30
45 d	———	3,72
46 c	———	3,47
51	———	4,15
μ	———	3,25
16	———	3,40
1 $\varkappa$	Cygni	3,68

10 ι	Cygni	3,55
η	Ursæ	3,67
ζ	——	3,87
85 ι	Herculis	4,52
υ	——	4,14
52	——	4,04
22 τ	——	4,16
α	Persei	2,28
	Capella	5,80

At Arbury Hill.

β	Draconis	2,71
γ	——	2,92
45 *d*	——	3,65
46 *c*	——	3,21
51	——	2,89
1 κ	Cygni	3,22
10 ι	——	2,48
γ	Ursæ	4,08
η	——	2,79
ζ	——	3,00
22 τ	——	4,01
α	Persei	2,63
	Capella	2,89

At Greenwich.

β	Draconis	4,07
γ	——	4,57
45 *d*	——	4,05
51	——	3,81
1 κ	Cygni	3,74
10 ι	——	4,44
γ	Ursæ	5,65
η	——	3,70
	Capella	4,50

Amplitudes of the celestial Arc comprehended by the Stations Dunnose and Clifton.

β *Draconis.*

	°	′	″
Zenith distance at Dunnose	1	50	5,24
Ditto - Clifton -	1	0	17,84
Amplitude of arc - -	2	50	23,08

γ *Draconis.*

Zenith distance at Dunnose	0	53	56,63
Clifton -	1	56	26,64
Amplitude of arc -	2	50	23,27

45 *d Draconis.*

Zenith distance at Dunnose	6	16	47,66
Clifton -	3	26	22,92
Amplitude of arc -	2	50	24,74

51 *Draconis.*

Zenith distance at Dunnose	2	28	44,05
Clifton -	0	21	38,12
Amplitude of arc -	2	50	22,17

46 *c Draconis.*

Zenith distance at Dunnose	4	43	28,93
Clifton -	1	53	6,24
Amplitude of arc -	2	50	22,69

16 *Draconis.*

Zenith distance at Dunnose	2	42	33,26
Clifton -	0	7	51,25
Amplitude of arc -	2	50	24,51

μ *Draconis.*

Zenith distance at Dunnose	4	6	59,30
Clifton -	1	16	38,20
Amplitude of arc -	2	50	21,10

10 *ι Cygni.*

Zenith distance at Dunnose	0	41	40,68
Clifton -	2	8	42,22
Amplitude of arc -	2	50	22,90

1 *κ Cygni.*

Zenith distance at Dunnose	2	23	22,86
Clifton -	0	27	0,32
Amplitude of arc -	2	50	23,18

η *Ursæ.*

	°	′	″
Zenith distance at Dunnose	0	18	42,93
Clifton -	3	9	6,98
Amplitude of arc -	2	50	24,05

γ *Ursæ.*

Zenith distance at Dunnose	4	10	36,23
Clifton -	1	20	13,53
Amplitude of arc -	2	50	22,70

ζ *Ursæ.*

Zenith distance at Dunnose	5	20	35,66
Clifton -	2	30	10,37
Amplitude of arc -	2	50	25,29

52 *Herculis.*

Zenith distance at Dunnose	4	17	1,28
Clifton -	7	7	25,45
Amplitude of arc -	2	50	24,17

85 *ι Herculis.*

Zenith distance at Dunnose	4	30	1,95
Clifton -	7	20	24,98
Amplitude of arc -	2	50	23,03

υ *Herculis.*

Zenith distance at Dunnose	4	1	33,24
Clifton -	6	51	56,80
Amplitude of arc -	2	50	23,56

22 τ *Herculis.*

Zenith distance at Dunnose	3	49	37,10
Clifton -	6	40	1,29
Amplitude of arc -	2	50	24,19

Capella.

Zenith distance at Dunnose	4	50	2,88
Clifton -	7	40	25,66
Amplitude of arc -	2	50	22,78

Amplitudes of the celestial Arc comprehended by the Stations Dunnose and Arbury Hill.

β Draconis.

	°	′	″
Zenith distance at Dunnose	1	50	5,24
Arbury Hill	0	13	45,82
Amplitude of arc -	1	36	19,42

γ Draconis.

Zenith distance at Dunnose	0	53	56,63
Arbury Hill	0	42	22,73
Amplitude of arc -	1	36	19,36

45 d Draconis.

Zenith distance at Dunnose	6	16	47,66
Arbury Hill	4	40	27,21
Amplitude of arc -	1	36	20,45

51 Draconis.

Zenith distance at Dunnose	2	28	44,01
Arbury Hill	0	52	24,42
Amplitude of arc -	1	36	19,59

46 c Draconis.

Zenith distance at Dunnose	4	43	28,93
Arbury Hill	3	7	9,30
Amplitude of arc -	1	36	19,63

1 κ Cygni.

	°	′	″
Zenith distance at Dunnose	2	23	22,86
Arbury Hill	0	47	2,92
Amplitude of arc -	1	36	19,94

10 ι Cygni.

Zenith distance at Dunnose	0	41	40,68
Arbury Hill	0	54	39,09
Amplitude of arc -	1	36	19,77

η Ursæ.

Zenith distance at Dunnose	0	18	42,93
Arbury Hill	1	55	4,63
Amplitude of arc -	1	36	21,70

Capella.

Zenith distance at Dunnose	4	50	2,88
Arbury Hill	0	26	22,90
Amplitude of arc -	1	36	20,02

Difference between the Parallels of Latitude of Dunnose and Greenwich.

β Draconis.

	°	′	″
Zenith distance at Dunnose	1	50	5,24
Greenwich	0	58	33,13
Difference of latitude	0	51	32,11

γ Draconis.

Zenith distance at Dunnose	0	53	56,63
Greenwich	0	2	24,39
Difference of latitude	0	51	32,24

45 d Draconis.

	°	′	″
Zenith distance at Dunnose	6	16	47,66
Greenwich	5	25	15,81
Difference of latitude	0	51	31,85

51 Draconis.

Zenith distance at Dunnose	2	28	44,05
Greenwich	1	37	14,25
Difference of latitude	0	51	29,90

1 κ Cygni.

Zenith distance at Dunnose	2	23	22,86
Greenwich	1	31	51,87
Difference of latitude	0	51	30,99

10 ι Cygni.

Zenith distance at Dunnose	0	41	40,68
Greenwich	0	9	49,60
Difference of latitude	0	51	30,28

γ Ursæ.

Zenith distance at Dunnose	4	10	36,23
Greenwich	3	19	4,67
Difference of latitude	0	51	31,56

η Ursæ.

Zenith distance at Dunnose	0	18	42,93
Greenwich	1	10	15,07
Difference of latitude	0	51	32,14

It will now be proper to exhibit the various results, as previously deduced; the amplitudes of the several arcs will then stand as follow.

Arc between Dunnose and Clifton.

	°	′	″	
β Draconis	2	50	23,08	
γ ———			23,27	
45 *d* ———			24,75	
46 *c* ———			22,69	
51 ———			22,17	
16 ———			24,51	
μ ———			21,10	Extreme results. Mean 23″,19, and might be rejected
ζ Ursæ			25,29	
γ ———			22,70	
η ———			24,05	
1 κ Cygni			23,18	
10 ι ———			22,90	
85 ι Herculis			23,03	
υ ———			23,56	
52 ———			24,17	
22 τ ———			24,19	
Capella			22,78	
Mean amplitude	2	50	23,38	

Between Dunnose and Arbury Hill.

β	Draconis	1° 36′	19″,42
γ	———		19,36
45 *d*	———		20,45
46 *c*	———		19,63
51	———		19,59
1 ϰ	Cygni		19,94
10 *i*	———		19,77
η	Ursæ		21,70
Mean amplitude		1 36	19,98

Between Dunnose and Greenwich.

β	Draconis	0° 51′	32″,11
γ	———		32,24
45 *d*	———		31,85
51	———		29,90
1 ϰ	Cygni		30,99
10 *i*	———		30,28
γ	Ursæ		31,56
η	———		32,14
Mean amplitude		0 51	31,39

It is very generally known that his Grace the Duke of MARLBOROUGH is possessed of an excellent quadrant, made by the late Mr. RAMSDEN, and that he has for some years been in the habit of using it at Blenheim. As my meridional line is not far eastward from his Grace's observatory, the zenith distance of any star or stars there determined, from a course of accurate observations, must afford me the means of ascertaining the lengths of the degrees on the meridian, at the middle points between Blenheim and the two extremities of my arc. I therefore applied to his Grace, requesting him to favour me with any observations he might have made, and with permission to publish

them, if I thought proper. His Grace was pleased to comply with my request; and I now avail myself of the advantage procured by that condescension.

Blenheim Observatory.

Zenith Distances of γ Draconis, reduced to the Beginning of the Year 1794, from Observations made in five successive Years, by his Grace the Duke of MARLBOROUGH.

From the observations of 1794, 0° 19′ 17″,32 γ Draconis south of the

1795	17,70	zenith.
1796	17,51	
1797	17,48	
1798	17,32	

Mean 0 19 17,46. Therefore, the mean zenith distance of γ Draconis, at Blenheim, on the 1st of January, 1802, may be taken at 0° 19′ 23″,06 south. The zenith distance of this star, at the same period, at the station Dunnose, as derived from the late operation, is 0° 53′ 56″,63 north; therefore, 0° 53′ 56″,63 + 0° 19′ 23″,06 = 1° 13′ 19″,69, is the difference of latitude between Dunnose and Blenheim observatory; and here, perhaps, it may not be improper to advert to page 675 of the Phil. Trans. for 1800, where the observed and computed latitudes are given, the former being 51° 50′ 24″,9, and the latter 51° 50′ 28″,1. The latitude of Dunnose is 50° 37′ 8″,21, that of Greenwich being taken at 51° 28′ 40″; and their difference 0° 51′ 31″,39, as derived from the observations made with the new sector. Hence, 50° 37′ 8″,21 + 1° 13′ 19″,69 = 51° 50′ 27″,9, must be the latitude of Blenheim, within a small part of a second of the truth. But it will be improper to dwell on this matter at present; and, therefore, I

shall conclude this article with giving, in order, the subtenses in the heavens, of the different parts of my terrestrial arc.

1.	Dunnose and Clifton	- -	2° 50′	23″,38
2.	Dunnose and Arbury Hill	-	1 36	19,98
3.	Arbury Hill and Clifton	- -	1 14	3,40
4.	Dunnose and Greenwich	-	0 51	31,39
5.	Greenwich and Clifton	- -	1 58	51,59
6.	Arbury Hill and Greenwich	-	0 44	48,19
7.	Dunnose and Blenheim	-	1 18	19,69
8.	Blenheim and Clifton	- -	1 37	3,69

Determination of the Lengths of the Degrees on the Meridian, in the middle Points of the several Arcs given in the last Article.

On a reference to the Phil. Trans. for 1800, it will be found, that Blenheim Observatory is 446458 feet from the perpendicular to the meridian of Dunnose. But the parallel to the perpendicular at Dunnose, from that observatory, where it cuts the meridian of the former, is about $\frac{4}{10}$ of a second in latitude north of the latter; therefore, 446498 feet may be taken for the distance of Blenheim north of Dunnose. This premised, we have the following terrestrial arcs, in conjunction with the preceding celestial ones, for computing the lengths of the several degrees.

	Arcs.		Feet.
1.	Dunnose and Clifton	- -	1036337
2.	Dunnose and Arbury Hill	- -	586320
3.	Arbury Hill and Clifton	- -	450017
4.	Dunnose and Greenwich	-	813696
5.	Greenwich and Clifton	- -	722641
6.	Arbury Hill and Greenwich	-	272624
7.	Dunnose and Blenheim	- -	446498
8.	Blenheim and Clifton	- -	589839

And, by simply dividing the terrestrial arcs by their corresponding celestial ones, and afterwards multiplying the several quotients by 3600″, we shall get the lengths of the degrees as follows.

	Fathoms.
Middle point between Dunnose and Clifton -	60820
Dunnose and Arbury Hill -	60864
Arbury Hill and Clifton -	60766
Dunnose and Greenwich -	60884
Greenwich and Clifton -	60794
Arbury Hill and Greenwich	60849
Blenheim and Clifton -	60769
Blenheim and Dunnose -	60890

Taking the latitude of Greenwich at 51° 28′ 40″, from the several arcs now given, the latitudes of their middle points are easily found; and, with the lengths of the degrees, when properly arranged, will stand as follows.

	Latitude of middle point	Fathoms.
Arbury Hill and Clifton -	52° 50′ 29″,8	60766
Blenheim and Clifton - -	52 38 56,1	60769
Greenwich and Clifton -	52 28 5,7	60794
Dunnose and Clifton - -	52 2 19,8	60820
Arbury Hill and Greenwich	51 51 4,1	60849
Dunnose and Arbury Hill -	51 35 18,2	60864
Blenheim and Dunnose -	51 13 18,2	60890
Dunnose and Greenwich -	51 2 54,2	60884

Note. The altitude of Arbury Hill, above the level of the sea, is 804 feet. The altitudes of the stations southward of Arbury Hill, are given in the former accounts of the trigonometrical operations: those to the northward of Arbury Hill may be found from the following *data*.

At Sutton, Heathersedge, elev. 15′ 25″; Gringley, dep. 18′ 47″.—*At Castle Ring*, Orpit Heights, dep. 5′ 26″; Bardon Hill, dep. 6′ 48″; Corley, dep. 14′ 26″.—*At Heathersedge*, Orpit Heights, dep. 20′ 27″.—*At Clifton*, Heathersedge, elev. 2′ 12″; Gringley, dep. 13′ 40″.—*At Hollan Hill*, Bardon Hill, elev. 2′ 35″; Orpit Heights, elev. 12′ 0″; Sutton, elev. 7′ 12″.—*At Bardon Hill*, Corley, dep. 16′ 3″; Arbury Hill, dep. 16′ 8″; Castle Ring, dep. 12′ 30″; Sutton, dep. 19′ 48″; Orpit Heights, dep. 6′ 35″.

CONCLUSION.

From this measurement it appears, that the length of a degree on the meridian, in latitude 52° 2′ 20″, is 60820 fathoms. This conclusion is deduced from the supposition of the whole arc subtending an angle of 2° 50′ 23″,38 in the heavens, and a distance of 1036337 feet on the surface of the earth.

The length of the degree at the middle point (51° 35′ 18″) between the southern extremity of the arc and Arbury Hill, is 60864 fathoms; which is greater than the above, and exceeds it by 44 fathoms. But this degree, admitting the earth to be an ellipsoid, with the ratio of its axes as 229 to 230, should be about 10 fathoms less. If the measurement of the terrestrial arc be sufficiently correct, and the earth of an elliptical form in these latitudes, either the arcs affording the deductions are incorrect, or some material deflection of the plumb-line has taken place, at one or two stations, from the effect of attraction.

Without arrogating to myself any merit from the pains taken in the performance of this undertaking, I may say, I am so perfectly convinced of the general accuracy of the whole, that I cannot for a moment doubt the collective evidence of its sufficiency. From an examination of my field books, and from the remeasurement of the chains used in our base-line on Misterton Carr, I think it is probable that an error in the whole distance, of 197 miles nearly, does not subsist to an amount of more than 100 feet, corresponding to 1″ in the amplitude of the whole arc; and I also think it probable it cannot amount to half that quantity. The supposition of the zenith distances of the stars being generally erroneous, at any one station, cannot be admitted, unless it should be imagined, that the plane of the

sector's limb was not got into that of the meridian. Such an idea, however, can scarcely be entertained, after a careful examination of the several observations, and a due attention to the means by which the instrument was made to assume its right position. Perhaps, also, I should not fail to observe, in this place, that although the instrument was always brought into the plane of each meridian by means of the telescope attached to the side of the great tube, and the azimuth circle, yet, having two good chronometers in my possession, I repeatedly verified the truth of the sector's position, by observing the transits of two stars, north and south of the zenith, at the greatest distances my arc would admit of. But, to return, if there be an error in the amplitude of the total arc, from a deflection of the plumb-line at either of the stations, it is not probable that any such deflection existed at Dunnose; as the deviation of it towards the north, from a deficiency of matter towards the channel, would tend to diminish the inequality between the lengths of the two degrees. This will be evident, on consideration. I am therefore disposed to believe that the plumb-line was drawn towards the south, from the action of matter, both at the northern extremity of the arc and at Arbury Hill, but more particularly at the first-mentioned station. If this were partly the case, and both Dunnose and Arbury Hill were free from any such prevailing cause, the total arc must be too great, if taken at 2° 50′ 23″,38, by about 8″, nearly answering to 2″ on each degree. A deviation of 8″ from the true vertical, is a large quantity; nor can the cause of it be assigned, unless it be also supposed, that the matter producing that deflection extends in a southern direction *beyond* Arbury Hill. If the error, though not probable, as above observed, be supposed to exist at Dunnose, it must amount to

more than 10″; and that too from the effects of attraction in a southern direction, where the deficiency of matter would lead us to believe the reverse would happen.

I am perfectly aware that it is possible to state a case, in which the plumb-line of a sector would deviate from the true vertical by such a quantity. Thus, for instance, in a chalky county, like the southern part of the kingdom, if the instrument were set up adjoining the terminations of two strata running east and west, one of chalk and the other of much denser materials, the effect would be as we have found it. But, at Dunnose, this argument does not apply; nor is there reason to believe, from external appearances, that it will do so, with regard either to Arbury Hill or the northern extremity of the meridional line.

It was the discovery of the disagreement between the subtense in the heavens, of the whole arc, and its corresponding terrestrial one, with those of its parts, which led me to apply to his Grace the Duke of MARLBOROUGH, for the observations made at Blenheim on γ Draconis, or some other star. His Lordship's compliance with my request, is shown, from the Table of results, to be serviceable; as the arc contained between the observatory at Blenheim and Dunnose, deduced from his Grace's observations, and those made at the latter place, with the meridional distance 446498 feet, give 60890 fathoms, for the length of the degree on the meridian in latitude 51° 13′; which agrees nearly with the length of the degree at the middle point between Greenwich and Dunnose. However, under all considerations of the means by which the degree in 51° 13′ has been obtained, I am inclined to believe there is an uncertainty in it, of 6 or 7 fathoms, answering to about $\frac{1}{2}$″ in latitude.

But, if the measured space between his Grace's observatory and

Dunnose, with its amplitude, (1° 13′ 19″,69) be used in finding the meridional distance of the whole arc, (its corresponding amplitude,) we shall get 2° 50′ 11″,80 for its subtense; which argues a deflection from the vertical at Clifton = 11″,79. If the meridional distance between Dunnose and Greenwich be used, we shall, from the same mode of proceeding, make it = 10″,3. In short, the general tenor of the observations seems to prove, that the plumb-line of the sector has been drawn towards the south at all the stations; and that by attractive forces, which increase as we proceed northward. On a further prosecution of this Survey, the zenith sector will be taken forward in that direction, which will afford an opportunity of throwing further light on this interesting subject. But meridional operations carried on in insular countries, are not so likely to afford just conclusions with regard to the different lengths of the degrees, as the same operations conducted in places very remote from deep seas.

From the late operations of the French Academicians it appears, that the meridional distance between Dunkirk and Barcelona is 275792,36 modules, the metre being 443,296 lines of the Peru toise = 0,256587th part of the module, at the temperature of melting ice. This meridional distance, therefore, converted into English feet, is 3527921. The distance between Dunkirk and Paris is 133758 feet, and the distance between Paris and Greenwich = 963954 feet; therefore, 830196 feet is the distance between Greenwich and Dunkirk. The distance between Greenwich and Clifton is 722641 feet; hence, 4411968 feet is the meridional distance between Clifton and Barcelona. The latitude of Barcelona is 41° 21′ 48″,8; the latitude of Greenwich is 51° 28′ 40″; and if to this latitude we add 1° 58′ 51″,59, the arc between Clifton and Greenwich, we shall get

53° 27′ 31″,59 for the latitude of Clifton; and shall then have the difference of latitude between Barcelona and Clifton = 12° 5′ 42″,79, something more than the 30th part of the whole circumference of the earth. With this difference of latitude, and the abovementioned distance, we shall get 60795 fathoms for the mean length of a degree on the earth's surface, in latitude 47° 24′. The latitude of Paris is 48° 50′ 15″; this, with that of Clifton, gives 4° 37′ 16″,59 for the difference between their parallels. The meridional distance is 1686595 feet; hence, 60825 fathoms, is the length of the degree in latitude 51° 9′.

With regard to the latitudes of places published in our former papers, those referred to the meridian of Greenwich are to remain uncorrected, since the computations were made with nearly the same length of a degree on the meridian, as that at the middle point, now deduced, between Dunnose and Greenwich, *viz.* 60884 fathoms. As to those places referred to the new meridian, *viz.* Dunnose, Butterton, and St. Agnes Beacon, 1″ is to be added to the latitudes of them all; because the latitude of Dunnose became the standard, which was then computed to be 50° 37′ 7″,3, but is now found, from the zenith distances of the stars observed there and at Greenwich, to be 50° 37′ 8″,2.

By way of Appendix to this Paper, I shall subjoin the latitudes and longitudes of those places intersected in the survey of Essex, Suffolk, &c. whose distances from their respective places of observation are given in the Phil. Trans. for 1800; this cannot but be highly useful, as they may be depended on, the interior survey of those parts having since proved that no erroneous intersections were made.

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APPENDIX.

Bearings of the principal Stations in the Counties of Essex, &c. from the Parallels to the Meridian of Greenwich; and likewise their Distances from that Meridian.

Names of stations.		Bearings.			Distance from meridian.	Mean.	Distance from perpendicular.	Mean.
		°	′	″	Feet.	Feet.	Feet.	Feet.
Severndroog	New Station, Wrotham	46	27	19 SE	71978	71977 E	59145	59144½ S
Old Station, Wrotham		38	43	11 NE	71976		59144	
Severndroog	Gravesend	80	53	20 SE	84888	84881/2 E	15434	15433½ S
New Station, Wrotham		16	27	19 NE	84889		15433	
Severndroog	Langdon Hill	68	48	4 NE	96515	96515 E	27920	27920½ N
Gravesend		15	0	39 NE	96515		27921	
Gravesend	Hadleigh	49	32	32 NE	133643	133643½ E	26145	26145 N
Langdon Hill		87	15	37 SE	133644		26145	
Hadleigh	Halstow	7	45	59 SW	129041	129040 E	7607	7607 S
Gravesend		79	36	53 NE	129039		7607	
Gravesend	Gads Hill	58	24	46 SE	105603	105603 E	23629	23629 S
Halstow		55	38	32 SW	105603		23629	
Gad's Hill	Sheppey	88	46	1 NE	176273	176273 E	22108	22108½ S
Halstow		72	55	56 SE	176273		22109	
Hadleigh	South End	80	11	2 SE	160836	160836 E	21441	21441 N
Sheppey		19	31	7 NW	160836		21441	
Halstow	Rayleigh	11	17	7 NE	138709	138709½ E	40851	40850½ N
Sheppey		30	49	17 NW	138710		40850	
Halstow	Prittlewell	42	47	6 NE	160844	160844 E	26757	26756½ N
Sheppey		17	31	22 NW	160844		26756	
Halstow	Canewdon	33	18	22 SE	168413	168413 E	51908	51907½ N
Sheppey		6	16	7 NW	168413		51907	
Halstow	Flagstaff, Sheerness	86	3	48 SE	170376	170374½ E	10451	10449 S
Hadleigh		45	6	25 SE	170373		10447	
Rayleigh	Danbury	9	55	10 NW	130525	130528½ E	87654	87664 N
Frierning		71	57	58 NE	130531		87664	
Langdon Hill		29	39	21 NE	130530		87662	
Severndroog	Frierning	42	23	31 NE	83919	83919 E	72488	72487½ N
Langdon Hill		15	46	56 NE	83919		72487	
Rayleigh	Signal Staff, Shoeburyness	59	55	0 SE	179732	179734 E	17086	17089 N
Langdon Hill		82	35	14 SE	179736		17093	
Rayleigh	Old Station, Tiptree	13	45	9 NE	156314	156314 E	112779	112785 N
Danbury		45	44	2 NE	156310		112790	
Frierning		60	53	59 NE	156320		112786	
Tiptree*	Tillingham Steeple	54	44	17 SE	200547	200544½ E	81511	81514 N
Danbury		84	58	57 SE	200542		81518	

* Triptree, by mistake, in the former part of this Survey.

Names of stations.		Bearings.			Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″	Feet.	Feet.		Feet.	Feet.	
Danbury -	Peldon	62	33	13 NE	200463	200464	E	123986	123984	N
Tillingham -		0	6	23 NW	200465			123983		
Peldon -	Flagstaff, St. Osyth Priory	83	48	39 SE	243805	243808	E	119284	119283	N
Tillingham -		48	52	57 NE	243812			119282		
Danbury -	Great Tey	30	12	45 NE	169380	169381	E	154381	154381	N
Peldon - -	Steeple	45	38	20 NW	169382			154381		
Peldon -	Stoke Steeple	0	35	41 NE	201127	201127	E	187921	187921	N
Great Tey -		43	25	34 NE	201127			187921		
Peldon -	Thorp Steeple	75	21	46 NE	263163	263163	E	140362	140359	N
Stoke - -		52	30	43 SE	263164			140358		
Peldon -	Little Bentley	60	4	57 NE	244846	244846	E	149523	149523	N
Thorp - -		63	25	21 NW	244846			149523		
Little Bentley -	Dover Court	63	32	9 NE	283323	283322	E	168677	168676	N
Thorp -		35	26	59 NE	283321			168675		
Tillingham -	West Mersea	11	58	27 NE	206545	206544	E	109809	109810	N
Danbury -		73	45	20 NE	206543			109811		
Great Tey -	St. Mary's, Colchester	84	22	42 SE	202276	202276	E	151143	151143	N
Stoke - -		1	47	26 SE	202276			151143		
St. Mary's Colchester -	Little Bromley	76	2	46 NE	234987	234987	E	159270	159270	N
Stoke -		49	45	52 SE	234988			159270		
Thorp - -		14	37	54 NW	250358			189406		
Dover Court -	Tattingstone	57	50	38 NW	250351	250353	E	189405	189402	N
Stoke -		88	17	13 NE	250350			189393		
Tattingstone -	Rushmere	35	36	22 NE	270865	270864	E	218047	218048	N
Dover Court -		14	9	47 NW	270864			218050		
Rushmere -	Falkenham	52	35	7 SE	302055	302054	E	194188	194189	N
Dover Court -		36	17	7 NE	302054			194190		
Rushmere -	Woodbridge	69	24	43 NE	295524	295524	E	227311	227311	N
Falkenham -		11	9	17 NW	295524			227312		
Woodbridge -	Butley Steeple	85	40	43 NE	329485	329485	E	229878	229878	N
Falkenham -		37	32	43 NE	329485			229879		
Falkenham -	Light House, Orford	59	30	44 NE	354267	354266	E	224929	224929	N
Butley -		78	42	16 SE	354266			224931		
Rushmere -	Otley Steeple	6	39	43 NE	274256	274254	E	247089	247088	N
Woodbridge -		47	5	17 NW	274252			247087		
Otley - -	Henley Steeple	53	4	43 SW	259074	259075	E	235681	235681	N
Rushmere -		33	45	47 NW	259076			235681		
Henley - -	Copdock Steeple	23	3	13 SW	245556	245557	E	203918	203917	N
Rushmere -		60	49	13 SW	245559			203917		
Copdock -	Naughton Steeple	51	26	57 NW	214045	214045	E	229030	229030	N
Henley - -		81	35	53 SW	214046			229030		
Great Tey -	Twinstead Steeple	12	47	14 NW	161215	161206	E	161198	161198	N
Stoke - -		86	26	30 NW	161198			161198		
Stoke -	Lavenham	28	18	20 NW	178348	178348	E	230216	230216	N
Glemsford -		87	4	35 NE	178348			230216		
Stoke -	Bulmer	73	17	13 NW	154916	154915	E	201792	201792	N
Lavenham -		39	30	10 SW	154915			201793		

Names of stations.		Bearings.	Distance from meridian.	Mean.	Distance from perpendicular.	Mean.
		° ′ ″	Feet.	Feet.	Feet.	Feet.
Lavenham -	Glemsford	87 4 35 SW	152635	152636 E	228903	228903 N
Bulmer - -		4 48 30 NW	152636		228903	
Bulmer -	Toppesfield •	77 14 50 SW	120796	120796 E	194070	19 069 N
Lavenham -		57 52 10 SW	120796		194069	
Severndroog	Southweald	39 49 54 NE	61300	61298 E	52599	52596 N
Langdon Hill		54 59 11 NW	61296		52593	
Tiptree -	Gallywood Common	57 45 6 SW	120796	120796 E	80657	80658 N
Danbury -		74 25 56 SW	120796		80659	
Gallywood Common - -	Pleshey •	17 28 50 NW	93384	93385 E	118789	118787 N
Tiptree -		84 33 10 NW	93386		118786	
Gallywood Common - -	High Easter	33 14 20 NW	79208	79208 E	120610	120611 N
Pleshey -		82 39 50 NW	79209		120612	
Danbury -	Hatfield Oak	62 7 31 NW	55309	55306 E	127468	127466 N
Pleshey -		77 9 51 NW	55303		127464	
Pleshey - -	Beauchamp Roding	63 25 9 SW	64941	64940 E	104555	104555 N
Hatfield Oak		22 49 0 SE	64940		104556	
Danbury -	Thaxted	31 33 51 NW	77490	77481 E	174002	173995 N
Lavenham -		60 52 10 SW	77475		174000	
Stoke - -		83 34 10 SW	77480		173985	
Severndroog	Brentwood Spire	44 23 29 NE	68984	68984 E	52063	52061 N
Langdon Hill		48 45 17 NW	68984		52060	
St. Paul's -	Old Station, High Beech	29 8 28 NE	8117	8117 E	67219	67219 N
Severndroog		4 44 36 NW	8117		67219	
St. Paul's -	Station, Hampstead	43 14 15 NW	39822	39824 W	32055	32055 N
High Beech -		53 44 33 SW	39826		32056	
St. Paul's -	New Station, High Beech	28 45 2 NE	7661	7661 E	67265	67264 N
Old Station, High Beech -		84 18 44 NW	7661		67264	
High Beech -	Epping Mill	53 4 40 NE	21742	21742 E	77457	77457 N
Severndroog		5 24 9 NE	21742		77457	
High Beech -	Berkhampstead Gazebo	46 15 36 NW	27987	27990 W	101790	101788 N
Epping Mill		63 56 1 NW	27993		101786	
Hatfield Oak -	Nasing Steeple	55 36 7 SW	10875	10875 E	97046	97046 N
Hatfield Oak	Henham on the Mount	0 35 42 NE	55710	55701 E	166727	166701 N
Thaxted -		71 24 58 SW	55692		166674	
Henham -	Thorley Steeple	36 40 8 SW	32376	32366 E	135373	135377 N
Hatfield -		70 57 48 NW	32356		135381	
Henham - -	Elmdon	35 5 52 NW	29669	29664 E	203744	203730 N
Thaxted -		58 8 32 NW	29660		203717	
Elmdon -	Rickling	22 34 52 SE	40925	40928 E	176651	176657 N
Henham -		55 59 52 NW	40931		176664	
Elmdon - -	Albury	11 37 43 SW	19669	19660 E	155071	155072 N
Henham -		72 6 30 SW	19651		155073	
Elmdon -	Balsham	49 57 18 NE	71969	71969 E	239285	239278 N
Thaxted -		4 49 38 NW	71970		239272	

• Topplesfield, • Pleshley, } by mistake, in the former part of this Survey.

Names of stations.		Bearings.				Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″		Feet.	Feet.		Feet.	Feet.	
Elmdon -	Babraham	26	18	32	NE	48970	48976	E	242777	242770	N
Balsham -	Mount	81	22	4	NW	48982			242762		
Elmdon -	Triplow	13	27	58	NW	23888	23891	E	227854	227850	N
BabrahamMount		59	15	2	SW	23894			227846		
Langdon Hill	Hornchurch	87	1	36	NW	51738	51747	E	30245	30246	N
Severndroog		47	41	55	NE	51744			30248		
Gravesend -	Purfleet Cliff	60	30	51	NW	53972	53974	E	2048	2050	N
Hornchurch -		4	31	59	SE	53976			2050		
Severndroog	Barking	7	57	53	NE	17541	17544	E	20068	21069	N
Hornchurch -		74	58	39	SW	17547			21070		
St. Paul's -	Westham	71	14	54	NE	2265	2264	E	21387	21387	N
Severndroog		24	48	33	NW	2264			21388		

Bearings of secondary Objects, &c.

Severndroog	Chigwell	4	30	54	NE	18578	18581	E	53508	53510	N
Highbeech -		37	21	14	SE	18585			53513		
Severndroog	Billericay	54	20	37	NE	95374	95373	E	54286	54286	N
Frierning -	Chapel	32	10	59	SE	95373			54286		
Hornchurch	Chimney of	60	27	19	SW	22826	22821	E	13857	13855	N
Barking -	Public House	36	9	21	SE	22817			13853		
Purfleet Cliff	Rainham	38	43	29	NW	43722	43723	E	14835	14835	N
Hornchurch -	Steeple	27	29	1	SW	43725			14836		
Hornchurch	Belvidere	27	18	51	SW	37806	37807	E	3263	3266	N
Purfleet -		85	40	59	NW	37808			3270		
Hornchurch -	Valence Tree	89	28	19	NW	31338	31335	E	30434	30432	N
Purfleet -		38	34	59	NW	31332			30430		
Rainham -	Cold Harbour	3	1	31	SW	43138	43137	E	3762	3761	N
Purfleet -		81	1	59	NW	43137			3760		
Gravesend -	Chadwell	1	13	50	NW	84524	84524	E	1570	1570	N
Severndroog	Steeple	85	25	30	NE	84524			1571		
Gravesend -	Greys Steeple	36	52	50	NW	73799	73799	E	653	653	S
Chadwell -		72	17	30	SW	73799			653		
Gravesend -	Flagstaff, Mr.	38	59	50	NW	70491	70491	E	2348	2347	N
Chadwell -	Button's	86	49	50	NW	70491			2347		
Gravesend -	West Thur-	52	56	50	NW	66967	66967	E	1902	1902	S
Chadwell -	rock Steeple	78	48	40	SW	66967			1903		
Gravesend -	West Tilbury	17	38	10	NE	89420	89420	E	1181	1181	S
Chadwell -	Steeple	60	40	20	SE	89421			1181		
Gravesend -	Northfleet	70	45	17	NW	76623	76623	E	12548	12548	S
Chadwell -	Steeple	29	13	52	SW	76623			12549		
Gravesend -	Horndon Spire	13	10	9	NE	92494	92496	E	17070	17072	N
Hornchurch -		72	5	26	SE	92498			17074		
Gravesend -	Flagstaff, East	56	2	10	NE	98431	98431	E	6312	6312	S
Chadwell -	Tilbury	60	27	20	SE	98432			6313		
Gravesend -	Fobbing	34	47	40	NE	108532	108534	E	18591	18591	N
Halstow -	Steeple	38	2	57	NW	108535			18592		

Names of stations.		Bearings.				Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″		Feet.	Feet.		Feet.	Feet.	
Halstow	Thundersley Steeple	1	36	20	NE	—	130198	E	—	33719	N
Sheppey	Leigh Steeple	30	29	48	NW	149211	149211	E	23840	23839	N
Halstow		32	40	43	NE	149211			23838		
Prittlewell	Little Wakering Steeple	76	58	11	NE	179943	179940	E	31175	31176	N
Canewdon		29	38	19	SE	179937			31178		
Prittlewell	Bank Flagstaff	83	58	11	NE	192575	192572	E	30108	30109	N
Canewdon		48	15	19	SE	192570			30110		
Bank Flagstaff	Foulness Chapel	33	4	41	NE	203200	203199	E	46426	46426	N
Canewdon		81	6	49	SE	203198			46427		
Tillingham	Tillingham Grange Signal Staff	40	45	13	SE	209676	209676	E	70916	70917	N
Peldon		9	50	52	SE	209676			70918		
Tillingham	Bradwell Point Signal Staff	43	21	35	NE	213453	213453	E	95184	95185	N
Peldon		24	16	41	SE	213453			95187		
Tillingham	Brightlingsea Steeple	30	56	17	NE	229383	229382	E	129627	129627	N
Peldon		78	57	17	NE	229381			129628		
Tillingham	Toleshunt Major	47	39	58	NW	173531	173531	E	106122	106123	N
Peldon		56	27	2	SW	173531			106124		
Tillingham	Tolesbury Steeple	27	50	13	NW	189052	189051	E	103277	103278	N
West Mersea		69	31	40	SW	189050			103279		
Tillingham	Althorn Steeple	61	20	37	SW	172511	172512	E	66194	66192	N
Tiptree		19	10	14	SE	172513			66191		
Althorn	Burnham Steeple	62	50	23	SE	185324	185324	E	59619	59620	N
Tillingham		34	48	27	SW	185324			59621		
Langdon Hill	Rettenden Steeple	45	18	38	NE	126748	126747	E	57827	57822	N
Rayleigh		35	11	19	NW	126747			57817		
Langdon Hill	Runwell Steeple	44	47	13	NE	121154	121151	E	52743	52740	N
Rayleigh		55	54	27	NW	121148			52737		
Rayleigh	Great Burstead Steeple *	82	34	27	NW	96984	96987	E	46288	46293	N
Danbury		39	2	12	SW	96990			46299		
Gallywood Common	East Hanningfield Steeple	63	53	54	SE	125885	125884	E	70617	70618	N
Danbury		15	14	49	SW	125884			70619		
Canewdon	Hockley Steeple	82	24	42	SW	144794	144796	E	48798	48798	N
Danbury		20	9	38	SE	144799			48798		
Rettenden	Stow, St. Mary's	63	26	42	NE	147833	147836	E	68360	63358	N
Canewdon		50	59	18	NW	147839			68357		
Frierning	Stock Steeple	71	54	14	SE	99912	99912	E	67262	67261	N
Danbury		56	19	22	SW	99912			67261		
Tiptree	Southminster Steeple	36	6	6	SE	188765	188762	E	68286	68289	N
Tillingham		41	42	29	SW	188760			68292		
Peldon	Layer Marney Steeple	82	30	52	NW	180456	180457	E	126613	126612	N
Tillingham		24	0	27	NW	180458			126612		
Peldon	St. Osyth Point Signal Staff	80	26	29	SE	260322	260323	E	113906	113905	N
Tillingham		61	33	1	NE	260324			113904		
Thorp Steeple	Great Clacton Sig. Staff	26	32	57	SE	272780	272780	E	121112	121111	N
Little Bentley		44	30	52	SE	272780			121111		

* Great Burghstead, by mistake, in the former part of this Survey.

Names of stations.		Bearings.				Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″		Feet.	Feet.		Feet.	Feet.	
Dover Court	Frinton *	10	50	11	SW	275991	275991	E	130375	130375	N
Thorp Steeple	Steeple	52	6	20	SE	275992			130375		
Thorp -	Great Clack-	3	45	53	SW	261921	261921	E	121481	121481	N
Peldon - -	ton Steeple	87	40	1	SE	261921			121481		
Dover Court -	Frinton Signal	3	49	35	SE	285637	285638	E	134068	134068	N
Thorp -	Staff	74	21	45	SE	285639			134068		
Dover Court	Walton Tower	17	48	27	SE	291358	291358	E	143661	143661	N
Thorp -		83	19	21	NE	291359			143661		
Dover Court	Cupola, Lan-	81	29	29	NE	298242	298242	E	170909	170909	N
Thorp - -	guard Fort	48	56	56	NE	298243			170909		
Thorp -	Ardleigh	58	21	57	NW	222726	222726	E	165270	165267	N
Peldon	Steeple	28	20	12	NE	222726			165265		
Great Tey -	Frating	78	10	31	SE	231313	231313	E	141415	141414	N
Peldon -	Steeple	60	31	56	NE	231313			141414		
Thorp -	Thorrington	86	16	44	SW	239323	239323	E	138810	138809	N
Little Bentley	Steeple	27	16	2	SW	239324			138809		
Thorp -	Kirby Steeple	84	44	24	SE	276355	276354	E	139146	139146	N
Dover Court -		13	16	47	SW	276353			139146		
Dover Court	Brantham	74	38	51	NW	242253	242254	E	179953	179951	N
Tattingstone	Steeple	40	35	22	SW	242255			179950		
Dover Court	Harwich	58	39	3	NE	290907	290909	E	173297	173297	N
Rushmere -	Steeple	24	7	47	SE	290911			173297		
Kirby Steeple	Little Oakley	5	5	13	NW	274475	274474	E	160255	160255	N
Dover Court		46	24	59	SW	274474			160255		
Dover Court -	Bawdsey	51	49	28	NE	319624	319624	E	197218	197217	N
Rushmere -	Steeple	66	51	57	SE	319625			197216		
Dover Court	Harkstead	45	2	45	NW	269208	269208	E	182770	182769	N
Rushmere -	Steeple	2	41	15	SW	269209			182768		
Dover Court -	Arwarton	24	33	8	NW	277899	277902	E	180550	180547	N
Tattingstone	Steeple	72	10	38	SE	277905			180544		
Tattingstone	Bradfield	6	0	38	SE	252552	252551	E	168520	168521	N
Arwarton -	Steeple	64	37	22	SW	252550			168523		
Falkenham -	Orford Steeple	51	16	53	NE	345336	345342	E	228887	228881	N
Rushmere -		81	43	43	NE	345349			228876		
Falkenham	Nacton Steeple	83	34	7	NW	277115	277115	E	197000	196998	N
Rushmere -		16	32	17	SE	277115			196997		
Dover Court	Capel Steeple	63	18	59	NW	233984	233986	E	193474	193468	N
Stoke -		80	25	43	NE	233988			193462		
Stoke - -	Great Horks-	22	8	14	SW	195997	195997	E	175309	175309	N
Great Tey -	ley Steeple	51	49	14	NE	195997			175310		
Great Horksley	Mount Bures	87	34	46	NW	174196	174195	E	176230	176230	N
Stoke -	Steeple	66	32	14	SW	174194			176231		
Rushmere -	Hollesley	82	8	17	SE	322258	322258	E	210952	210953	N
Dover Court	Steeple	42	38	33	NE	322258			210955		
Rushmere -	Shottisham	82	14	7	SE	311711	311720	E	212477	212477	N
Dover Court	Steeple	32	57	53	NE	311729			212477		
Woodbridge	Felixstow Sig-	16	45	47	SE	309444	309444	E	181100	181102	N
Dover Court -	nal Staff	64	33	24	NE	309444			181104		

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		°	′	″		Feet.	Feet.		Feet.	Feet.	
Woodbridge -	Bawdsey Signal Staff	33	7	47	SE	318758	318757	E	191712	191714	N
Dover Court		56	58	8	NE	318757			191716		
Butley -	Rendlesham	59	42	17	NW	313767	313761	E	239061	239058	N
Woodbridge	Steeple	57	12	43	NE	313755			239055		
Dover Court	Kesgrave	6	7	41	NW	278145	278145	E	216905	216904	N
Rushmere -	Steeple	81	3	47	SE	278146			216903		
Dover Court -	Waldringfield	20	4	29	NE	298893	298901	E	211282	211281	N
Rushmere -	Steeple	76	25	37	SE	298900			211282		
Dover Court	Whertstead	37	5	51	NW	258996	258995	E	200845	200844	N
Kesgrave -	Steeple	50	0	49	SW	258995			200843		
Capel Steeple	Hintlesham	3	26	17	NE	235016	235017	E	210623	210620	N
Stoke -	Steeple	56	11	25	NE	235019			210618		
Stoke - -	Bildestone	1	24	50	NE	202169	202168	E	230147	230147	N
Lavenham -	Steeple	89	50	0	SE	202168			230147		
Stoke - -	Aldham	35	18	30	NE	219654	219654	E	214079	214080	N
Bildeston -	Steeple	47	25	20	SE	219654			214081		
Naughton -	Hadleigh	1	12	40	SE	214492	214565	E	207881	207823	N
Lavenham -	Steeple	58	15	30	SE	214639			207766		
Naughton -	Lindsey	49	42	50	SW	199105	199177	E	216365	216308	N
Lavenham -	Steeple	56	15	10	SE	199249			216251		
Stoke -	Newton	51	25	50	NW	179897	179897	E	204850	204850	N
Lavenham -	Steeple	3	29	40	SE	179897			204850		
Stoke -	Grotton	24	24	50	NW	193001	193001	E	205823	205823	N
Newton -	Steeple	85	45	10	NE	193001			205823		
Bulmer -	Waldingfield	62	39	10	NE	177687	177690	E	213569	213540	N
Glemsford -	Steeple	58	26	20	SE	177693			213511		
Glemsford -	Acton Steeple	59	48	35	SE	171295	171295	E	218047	218047	N
Lavenham -		30	5	35	SW	171296			218047		
Bulmer -	Beauchamp	51	50	10	NW	140480	140478	E	213137	213135	N
Lavenham -	Ch. St. Paul's	59	43	20	SW	140476			213134		
Lavenham -	Hedingham	45	20	20	SW	136127	136128	E	188492	188492	N
Toppesfield	Castle	70	0	30	SE	136129			188492		
Lavenham -	Ridgewell	66	27	10	SW	121213	121213	E	205317	205316	N
Bulmer -	Steeple	84	1	50	NW	121214			205316		
Naughton -	Langham	2	52	7	SE	216543	216610	E	179186	179127	N
Stoke -	Steeple	50	22	7	SE	216690			179069		
Stoke -	Earles Colne	60	43	14	SW	159472	159471	E	164565	164565	N
St.Mary's, Colch.	Steeple	72	35	26	NW	159471			164565		
St. Mary's -	West Bergholt	51	8	42	NW	189552	189553	E	161393	161393	N
Great Tey -	Steeple	70	49	58	NE	189554			161393		
Danbury -	Braxted	36	18	45	NE	155021	155021	E	120989	120988	N
Great Tey -	Steeple	23	16	5	SW	155022			120988		
Braxted -	Kelverdon	11	32	29	NE	157104	157104	E	131184	131185	N
Great Tey -	Steeple	27	53	29	SW	157104			131186		
Great Tey -	Messing	2	21	21	SE	170301	170301	E	132010	132009	N
Kelverdon -	Steeple	86	25	29	NE	170302			132009		
Great Tey -	East Thorp -	23	49	41	SE	175627	175627	E	140237	140236	N
Kelverdon -		63	57	29	NE	175627			140236		

Names of stations.		Bearings.				Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″		Feet.	Feet.		Feet.	Feet.	
Tiptree -	Witham Steep.	56	46	32	NW	143890	143888	E	120923	120927	N
Danbury -		21	52	28	NE	143887			120932		
Tiptree -	Tarling Steeple	75	58	23	NW	129390	129388	E	119511	119513	N
Danbury -		7	3	23	NW	129386			119516		
Pleshey - -	Felstead Steeple	13	41	16	NE	98214	98210	E	138616	138613	N
Danbury -		32	23	31	NW	98207			138611		
Pleshey -	Great Leigh Steeple	81	44	16	NE	118041	118041	E	122359	122361	N
Felstead -		50	39	44	SE	118041			122363		
Pleshey -	Great Baddow Steeple	33	23	53	SE	114190	114191	E	87232	87229	N
Danbury -		88	27	53	SW	114191			87226		
Pleshey -	Chelmsford Steeple	29	41	53	SE	107349	107349	E	94258	94263	N
Danbury -		74	2	1	NW	107350			94288		
Danbury -	Whittle Steeple	82	41	29	NW	97251	97250	E	91931	91936	N
Pleshey -		8	41	33	SE	97249			91942		
Gallywood -	Roxwell Steeple	43	43	26	NW	86985	86986	E	99902	99903	N
Pleshey -		18	43	10	SW	86987			99905		
Gallywood -	White Roding Steeple	51	38	40	NW	59967	59967	E	116602	116604	N
Pleshey -		86	15	55	SW	59967			116606		
Frierning -	Doddinghurst Steeple	78	55	28	SW	67638	67644	E	69301	69304	N
Southweald		20	48	47	NE	67651			69308		
Southweald -	Theydon Mount Steep.	54	3	14	NW	36122	36125	E	70851	70859	N
Epping Mill		65	23	14	SE	36128			70867		
Southweald -	Navestock new Mill	4	50	14	NW	60484	60485	E	62217	62221	N
Theydon Mount		70	29	14	SE	60487			62226		
Southweald	Theydon Garnon Steeple	59	21	14	NW	29374	29363	E	71511	71461	N
Theydon Mount		85	20	14	NW	29351			71411		
Theydon Mount	Havering Steeple	16	39	44	SE	42172	42177	E	50654	50654	N
Theydon Garnon		31	42	14	SE	42183			50654		
Severndroog	Cupola at Woodford	10	24	56	NW	4584	4584	E	47329	47331	N
Highbeech -		10	4	28	SW	4584			47333		
Southweald	Ruins near Ilford	69	1	52	SW	13358	13357	E	34223	34225	N
Highbeech -		9	1	28	SE	13356			34227		
Nasing -	Hunsdon Steeple	5	57	9	NE	12836	12839	E	115758	115758	N
Berkhampstead Gazebo -		71	6	45	NE	12843			115758		
Huntsdon -	Broxbourn Steeple	40	38	9	SW	3021	3020	W	97376	97377	N
Nasing -		88	37	51	NW	3020			97378		
Danbury -	Willingale Spain Steeple	81	23	51	NW	70724	70725	E	96710	96713	N
Hatfield Oak		26	38	16	SE	70726			96716		
Danbury -	Braintree Steeple	5	52	1	NW	124508	124510	E	146272	146266	N
Felstead -		73	47	14	NE	124513			146261		
Hatfield Oak	Harlow Steep.	52	44	34	SW	33842	33846	E	111140	111081	N
Berkhampstead Gazebo -		81	29	13	NE	33850			111023		
Hatfield Oak	Sabridgeworth Steeple	74	50	17	SW	34982	34959	E	121958	122044	N
Nasing -		43	48	2	NE	34936			122136		

Names of stations.		Bearings.				Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″		Feet.	Feet.		Feet.	Feet.	
Albury -	Bishop Stort-	54	29	24	SE	35934	35929	E	143459	143454	N
Henham -	ford Steeple	40	22	56	SW	35925			143450		
Stanstead Mount-	Farnham	79	27	59	NW	34427	34425	E	154725	154723	N
fitchet Steeple	Steeple	69	37	6	SW	34423			154721		
Henham -	Stanstead										
Albury -	Mountfitchet	84	18	27	SE	47531	47526	E	152294	152289	N
Henham -	Steeple	29	34	6	SW	47522			152285		
Henham -		69	20	30	NW	19158	19162	E	180479	180483	N
Albury -	Meesdon Mill	1	6	40	NW	19167			180488		
Rickling -	Newport	41	50	8	NE	48409	48408	E	185013	185010	N
Elmdon -	Steeple	45	1	52	SE	48407			185007		
Balsham -		25	17	50	SE	82115	82114	E	217814	217818	N
Elmdon -	ShudyCamps*	74	57	40	NE	82114			217822		
Shudy Camps	Ashdon	55	23	10	SW	68848	68848	E	208661	208660	N
Balsham -	Steeple	5	49	20	SW	68848			208659		

Bearings of the principal Stations of the western Parts of Kent, &c. &c.

Frant -	Sevenoaks	19	20	53	NW	42962	42961	E	83270	83270	S
Botley Hill -	Mill	76	21	7	SE	42961			83271		
Frant -	Chiddingstone	41	38	3	NW	33852	33850	E	106413	106403	S
Sevenoaks Mill	Steeple	21	31	57	SW	33848			106394		
Frant -	Mount Sion	6	35	46	NW	55693	55691	E	80967	80962	S
Chiddingstone		40	38	14	NE	55690			80957		
Frant -	East Peckham	24	52	44	NE	87147	87146	E	84966	84963	S
Mount Sion	Steeple	82	45	16	SE	87145			84960		
East Peckham	Tudeley	32	3	44	SW	73465	73465	E	106804	106803	S
Mount Sion	Steeple	34	31	16	SE	73465			106803		
Sevenoaks -	Seal Chart	65	21	5	NE	59674	59673	E	75602	75601	S
Botley Hill		87	22	55	SE	59673			75601		
Sevenoaks	Tunbridge	47	49	55	SE	63789	63789	E	102135	102135	S
Seal Chart -	Steeple	8	48	55	SE	63789			102135		
Seal Chart	Otford Mount	36	37	55	NW	47503	47503	E	59233	59233	S
Sevenoaks -		10	42	5	NE	47503			59234		
Norwood -	Station, Well	68	30	7	SE	34094	34093	E	45635	45636	S
Severndroog	Hill	25	45	47	SE	34093			45638		
Well Hill -	Crayford	9	14	45	NE	40174	40173	E	8287	8287	S
Severndroog	Steeple	80	50	1	SE	40173			8288		
Crayford -	Ash Steeple	38	53	55	SE	68780	68780	E	43740	43741	S
Well Hill -		86	52	25	NE	68780			43742		
Gad's Hill -	Northfleet	69	4	54	NW	76615	76614	E	12548	12548	S
Halstow -	Steeple	84	36	53	SW	76614			12549		
Sheppey -	Hern Hill	48	45	30	SE	220216	220216	E	60633	60633	S
Frinstead -		80	51	12	NE	220217			60633		
Hern Hill -	Stockbury	85	47	30	NW	148806	148806	E	55379	55379	S
Sheppey -	Steeple	39	32	30	SW	148806			55379		
Sheppey -	Frinstead	15	23	54	SW	—	163132	E	—	698348	S

* Shady Camps, by mistake, in the former part of this Survey.

Bearings of the secondary and inferior Objects, &c. of the western Parts of Kent.

Names of stations.		Bearings.			Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″	Feet.	Feet.		Feet.	Feet.	
Frant - -	Bidborough	16	51	0 NW	54785	54786	E	113503	113506	S
Botley -	Steeple	53	21	9 SE	54787			113496		
Frant -	Station near	20	46	3 NW	52687	52685	E	113000	112995	S
Chiddingstone	Bidborough Church	70	43	3 SE	52684			112991		
Botley - -	Tree near Kib-	57	9	11 SE	83513	83515	E	126687	126689	S
Frant -	ben's Cross	60	56	36 NE	83518			126691		
Frant - -	Cowden	67	18	3 NW	23647	23679	E	122273	122270	S
Station near Bid-borough Church	Steeple	72	17	27 SW	23712			122268		
Station near Bid-borough -	Leigh Steeple	15	18	3 NW	49720	49731	E	102152	102164	S
Mount Sion		15	39	57 SW	49742			102175		
Frant - -	Station, Ide	31	32	33 NW	29621	29616	E	85152	85142	S
Chiddingstone	Hill	11	16	33 NW	29611			85132		
Ide Hill -	Eatonbridge*	38	26	27 SW	15562	15569	E	102848	102842	S
Chiddingstone	Steeple	78	58	33 NW	15557			102839		
Mount Sion	Hadlow	62	9	16 SE	78053	78055	E	92775	92777	S
Peckham -	Steeple	49	18	44 SW	78058			92779		
Otford Mount	Sundrich	49	33	5 SW	29901	29901	E	74241	74241	S
Seal Chart -	Steeple	87	22	55 NW	29901			74241		
Well Hill -	Ketson Com-	86	10	47 NW	7615	7614	E	43868	43867	S
Norwood -	mon Wind-mill	54	24	45 SE	7614			43867		
Well Hill -	Hayes Com-	82	24	47 NW	6068	6068	E	41903	41904	S
Severndroog	mon Flagstaff	11	53	13 SW	6068			41905		
Hayes Common	Addington	84	34	43 SW	11919	11912	E	43611	43608	S
Norwood -	Common Flagstaff	21	16	47 SE	11906			43606		
Well Hill -	Station, Farn-	84	46	47 NW	22492	22491	E	44576	44576	S
Severndroog	borough	11	47	47 SE	22491			44577		
Farnborough	St. Mary's	15	41	13 NE	26553	26553	E	30116	30116	S
Well Hill -	Cray	25	54	47 NW	26554			30116		
Well Hill -	Halstead	31	47	27 SW	29536	29535	E	52990	52990	S
Norwood -	Steeple	59	50	3 SE	29535			52990		
Norwood -	Bromley	85	1	7 SE	3304	3303	E	26574	26573	S
Severndroog	Steeple	25	29	23 SW	3303			26572		
Bromley -	Hayes Steeple	0	39	47 SE	4441	4447	E	36311	36318	S
Well Hill -		72	33	47 NW	4453			36326		
Bromley -	Lewisham	19	48	37 NW	3352	3353	W	8096	8096	S
Severndroog	Steeple	76	57	23 SW	3354			8097		
Chiselhurst -	New Cross	51	47	59 NW	9490	9490	W	3550	3550	S
Severndroog		88	43	59 NW	9491			3550		

* Edenbridge, by mistake, in the former part of this Survey.

Names of stations.		Bearings.				Distance from meridian.	Mean.		Distance from perpendicular.	Mean.	
		°	′	″		Feet.	Feet.		Feet.	Feet.	
Severndroog	Eastcombe	50	43	59	NW	86	86	E	7332	7332	S
New Cross	Point	41	21	1	NE	87			7332		
Severndroog	Woolwich	1	4	59	NW	13855	13853	E	5556	5556	N
Eastcombe Point	Steeple	82	38	59	SE	13852			5557		
Crayford	Bexley Steeple	41	21	39	SW	35426	35425	E	13679	13680	S
Severndroog		65	48	31	SE	35425			13681		
Well Hill	Charlton Farm	52	33	15	NW	15965	15965	E	31752	31751	S
Crayford		45	53	45	SW	15965			31751		
Crayford	Dartford Brent	69	26	13	SE	54059	54060	E	13496	13496	S
Ash	Mill	25	57	6	NW	54061			13497		
Ash	Hartley Steeple	29	56	5	NE	72706	72711	E	36922	36920	S
Northfleet		9	16	55	SW	72716			36918		
Ash	Ridley Steeple	64	4	45	SE	73446	73446	E	46009	46009	S
Northfleet		5	32	35	SW	73446			46010		
Gads Hill	Cliff Steeple	24	3	15	NE	113741	113741	E	5396	5396	S
Gravesend		70	49	7	NE	113742			5397		
Halstow	Gravesend Steeple	84	19	23	SW	84513	84517	E	12033	12058	S
Gravesend		6	19	23	NW	84518			12082		
Halstow	Chalk Steeple	71	45	9	SW	96111	96110	E	18464	18462	S
Gravesend		74	54	24	SE	96109			18460		
Gads Hill	Guard Room, Lower Hope Point	3	41	11	NE	107247	107247	E	1895	1894	N
Gravesend		52	13	26	NE	107247			1894		
Gads Hill	Flagstaff, Tilbury Fort	52	58	28	NW	86260	86260	E	9039	9040	S
Gravesend		12	6	7	NE	86260			9041		
Sheppey	Rainham Steeple	62	21	39	SW	139485	139484	E	41373	41372	S
Gads Hill		62	21	33	SE	139483			41372		
Halstow	Swanscombe Spire	84	51	25	SW	70463	70463	E	12880	12879	S
Gads Hill		72	59	24	NW	70464			12879		
Halstow	Southfleet Steeple	75	19	30	SW	73187	73187	E	22234	22234	S
Gravesend		59	50	13	SW	73187			22234		
Gravesend	Shorn Mill	61	26	17	SE	98017	98025	E	22580	22584	S
Halstow		64	12	53	SW	98034			22586		
Sheppey	Gillingham Steeple	78	54	49	SW	128724	128724	E	31425	31426	S
Halstow		0	45	32	SW	128725			31427		
Gillingham	St. James's, Isle of Grain	54	20	32	NE	163871	163871	E	6210	6209	S
Sheppey		37	57	19	NW	163871			6209		
Sheppey	Friendsbury Steeple	87	3	26	NW	115632	115631	E	18991	18991	S
Gads Hill		65	10	37	NE	115631			18991		
Sheppey	Star Inn	71	18	17	SW	128656	128656	E	38221	38221	S
Halstow		0	43	10	SW	128656			38222		
Sheppey	Upper Bell Inn	62	18	51	SW	116532	116532	E	53454	53441	S
Halstow		15	16	0	SW	116533			53431		
Sheppey	Upchurch Steeple	63	9	35	SW	148260	148250	E	36283	36266	S
Gads Hill		73	30	36	SE	148240			36251		
Frinstead	Hucking Spire	77	54	35	NW	147823	147822	E	66545	66545	S
Sheppey		32	37	45	SW	147822			66545		

Names of stations.		Bearings.	Distance from meridian.	Mean.	Distance from perpendicular.	Mean.
		° ′ ″	Feet.	Feet.	Feet.	Feet.
Hern Hill -	East Church	34 30 32 NW	196669	196678 E	26383	26376 S
Sheppey -		78 12 36 SE	196688		26369	
East Church -	Milton Steeple	57 27 7 SW	169440	169445 E	43761	43758 S
Sheppey -		17 29 46 SW	169450		43754	
Milton -	Iwade Steeple	14 54 14 NW	165705	165702 E	29703	29685 S
Sheppey -		54 26 16 SW	165700		29667	
Hern Hill -	Witchling	73 23 12 SW	170790	170789 E	75380	75380 S
Frinstead -	Steeple	54 2 13 SE	170789		75380	
Hern Hill -	Sheldwich	56 6 30 SW	202302	202291 E	72667	72675 S
Sheppey -	Steeple	27 12 48 SE	202280		72682	
Sheldwich -	Queenborough	31 53 48 NW	170208	170213 E	21124	21128 S
Sheppey -	Steeple	80 52 4 NW	170219		21133	
Halstow -	St. Mary's	77 55 24 NE	135978	135977 E	6123	6123 S
Hadleigh -	Steeple	4 8 17 SE	135977		6123	
Hern Hill -	Feversham	77 56 30 NW	204931	204930 E	57368	57368 S
Sheppey -	Steeple	39 6 8 SE	204930		57368	

Latitudes and Longitudes of the preceding Stations and Objects, referred to the Meridian of Greenwich.

Names of stations.	Latitudes.	Longitudes.	Names of stations.	Latitudes.	Longitudes.
	° ′ ″	° ′ ″		° ′ ″	° ′ ″
Highbeech -	51 39 42,5	0 2 8,3 E	Tiptree - -	51 47 2,2	0 41 17,8 E
Station, Hampstead -	51 33 55,4	0 10 28,0 W	Tillingham -	51 41 52,7	0 52 52,9 E
New Station, Wrotham -	51 18 55,5	0 18 49,2 E	Peldon -	51 58 50,3	0 53 11,4 E
Station, Gravesend - -	51 26 5,9	0 22 15,6 E	Flagstaff, St. Osyth Priory -	51 47 57,9	1 4 25,7 E
Langdon Hill	51 33 12,5	0 25 22,1 E	Great Tey -	51 53 53,2	0 44 49,9 E
Hadleigh -	51 32 52,5	0 35 7,4 E	Stoke -	51 59 20,4	0 53 22,6 E
Halstow - -	51 27 20,3	0 33 50,7 E	Thorp -	51 51 23,2	1 9 38,3 E
Gads Hill -	51 24 43,8	0 27 40,2 E	Little Bentley	51 52 56,3	1 4 49,7 E
Sheppey -	51 24 23,2	0 46 11,5 E	Dover Court	51 55 59,1	1 15 6,1 E
Rayleigh -	51 35 17,0	0 36 29,2 E	St. Mary's, Colchester -	51 53 17,7	0 53 33,7 E
Prittlewell -	51 32 56,2	0 42 16,2 E	West Mersea	51 46 29,8	0 54 33,3 E
Canewdon -	51 37 3,4	0 46 15,5 E	Little Bromley	51 54 43,4	0 39 16,8 E
Staff, Sheerness	51 11 21,6	0 44 25,7 E	Tattingstone	51 59 39,4	0 41 55,5 E
Danbury -	51 42 59,3	0 34 26,0 E	Rushmere -	52 4 7,3	1 12 0,8 E
Frierning -	51 40 32,5	0 22 7,0 E	Falkenham -	51 56 2,2	1 20 4,0 E
Purfleet Cliff -	51 28 59,4	0 14 9,9 E	Woodbridge -	52 5 34,6	1 18 36,8 E
South End -	51 32 4,4	0 42 15,5 E	Burley -	52 5 53,7	1 27 39,8 E
Staff, Shoeburyness -	51 31 19,1	0 47 12,6 E	Orford Light House -	52 5 0,1	1 34 13,6 E
			Otley -	52 8 54,1	1 13 2,5 E

Names of stations.	Latitudes.			Longitudes.				Names of stations.	Latitudes.			Longitudes.			
	°	′	″	°	′	″			°	′	″	°	′	″	
Henley - -	52	7	2,9	1	8	57,2	E	Flagstaff, East Tilbury -	51	27	36,0	0	25	49,2	E
Copdock -	52	1	51,9	1	5	13,2	E	Fobbing Steeple	51	31	39,8	0	28	30,7	E
Naughton -	52	6	3,5	0	56	56,7	E	Thundersley -	51	34	7,4	0	34	13,9	E
Twinstead -	51	59	48,4	0	42	47,2	E	Leigh - -	51	32	28,7	0	39	12,6	E
Lavenham -	52	6	19,1	0	47	27,0	E	Little Wakering	51	33	38,0	0	47	18,3	E
Bulmer - -	52	1	41,5	0	41	8,6	E	Bank Flagstaff	51	33	26,0	0	50	37,5	E
Glemsford -	52	6	8,8	0	40	36,4	E	Foulness Chapel	51	36	5,7	0	53	28,1	E
Toppesfield -	52	0	28,1	0	32	4,1	E	Tillingham Grange Signal Staff - -	51	40	6,2	0	55	15,2	
Gallywood Common -	51	41	51,8	0	27	47,7	E	Flagstaff, Bradwell Point -	51	44	5,0	0	56	19,8	E
Pleshey -	51	48	8,0	0	24	40,8	E	Brightlingsea	51	49	42,3	1	0	39,5	E
High Easter -	51	48	26,9	0	20	56,1	E	Tolesbunt Major	51	45	51,2	0	45	49,5	E
Hatfield Oak	51	49	35,5	0	14	37,4	E	Tolesbury -	51	45	27,6	0	49	54,9	E
Beauchamp Roding - -	51	45	48,9	0	17	8,8	E	Althorn -	51	39	23,8	0	45	26,8	E
Thaxted -	51	57	13,1	0	20	32,7	E	Burnham -	51	38	17,7	0	48	48,2	E
Southweald -	51	37	17,4	0	16	8,1	E	Rettenden -	51	38	5,2	0	33	22,4	E
Brentwood -	51	37	11,8	0	18	9,5	E	Runwell -	51	37	15,6	0	31	53,4	E
New Station, Highbeech -	51	39	42,9	0	2	1,1	E	Great Burstead	51	36	13,6	0	25	31,2	E
Epping Mill	51	41	23,3	0	5	43,8	E	East Hanningfield	51	40	11,4	0	33	10,2	E
Berkhampstead Gazebo -	51	45	23,0	0	7	23,3	E	Hockley -	51	36	34,9	0	38	6,3	E
Henham on the Mount -	51	56	1,7	0	14	45,7	E	Stow, St. Mary's	51	39	47,4	0	38	57,1	E
Thorley -	51	50	53,8	0	8	33,2	E	Stock Steeple -	51	39	40,0	0	26	19,3	E
Elmdon - -	52	2	7,3	0	8	3,8	E	Southminster	51	39	42,7	0	49	44,0	E
Rickling -	51	57	40,3	0	10	51,2	E	Layer Marney	51	49	13,7	0	47	42,6	E
Albury - -	51	54	8,1	0	5	12,4	E	St. Osyth Point Signal Staff -	51	47	3,0	1	8	46,5	E
Balsham -	52	7	56,1	0	19	9,6	E	Great Clackton Signal Staff	51	48	12,1	1	12	5,9	E
Babraham Mount	51	32	38,5	0	12	52,1	E	Frinton Steeple	51	50	26,8	1	12	28,4	E
Triplow -	52	6	5,0	0	6	21,3	E	Flagstaff, Frinton	51	50	17,8	1	15	33,4	E
Hornchurch -	51	33	37,3	0	13	36,1	E	Walton Tower	51	51	51,2	1	17	6,8	E
Barking -	51	32	7,5	0	4	36,5	E	Cupola, Languard Fort -	51	56	18,5	1	19	3,9	E
Westham -	51	32	10,6	0	0	35,7	E	Ardleigh -	51	55	34,3	1	59	1,5	E
Chigwell - -	51	37	27,2	0	4	53,4	E	Frating -	51	51	38,2	1	1	12,8	E
Billericay -	51	37	32,5	0	25	6,5	E	Thorrington -	51	51	10,0	1	3	19,4	E
Public House	51	30	56,3	0	5	59,6	E	Kirby - -	51	51	9,3	1	13	7,4	E
Rainham -	51	31	5,7	0	11	29,0	E	Brantham -	51	57	56,4	1	4	15,5	E
Belvidere -	51	29	11,7	0	9	55,3	E	Harwich -	51	56	43,3	1	17	7,8	E
Valence Tree	51	33	39,6	0	8	14,2	E	Little Oakley	51	54	37,3	1	12	42,9	E
Cold Harbour	51	29	16,5	0	11	19,3	E	Bawdsey -	52	0	38,8	1	24	52,1	E
Chadwell -	51	28	53,4	0	22	10,9	E	Harkstead -	51	58	20,2	1	11	25,2	E
West Tilbury	51	28	26,1	0	23	27,7	E	Arwarton -	51	57	56,8	1	13	42,9	E
Greys Steeple	51	29	1,7	0	18	30	E	Bradfield -	51	56	2,2	1	6	50,5	E
West Thurrock	51	28	20,0	0	17	34,2	E	Orford -	52	5	40,9	1	31	54,2	E
Northfleet -	51	26	34,6	0	20	5,4	E								
Horndon -	51	31	25,7	0	24	17,8	E								

Names of stations.	Latitudes.				Longitudes.			
	°	′	″		°	′	″	
Nacton	52	0	34,5		1	13	34,6	E
Capel	52	0	10,6		1	2	6,9	E
Great Horksley	51	57	16,5		0	51	58,4	E
Mount Bures	51	57	27,8		0	46	11,7	E
Hollesley	52	2	48,7		1	25	38,4	E
Shottisham	52	3	5,2		1	22	50,8	E
Felixstow Staff	51	57	56,9		1	22	5,1	E
Bawdsey Signal Staff	51	59	39,8		1	24	36,6	E
Rendlesham	52	7	27,2		1	23	31,5	E
Kesgrave	52	7	14,9		1	14	2,2	E
Waldringfield	51	56	56,1		1	19	26,0	E
Whertstead	52	1	19,6		1	8	47,1	E
Hintlesham	52	0	59,4		1	2	27,3	E
Bildestone	52	1	30,5		0	53	40,0	E
Aldham	52	3	35,5		0	58	23,1	E
Hadleigh	52	2	34,5		0	57	0,7	E
Lindsey	52	5	40,5		0	52	58,9	E
Newton	52	2	9,1		0	47	47,4	E
Grotton	52	2	23,6		0	32	21,1	E
Waldingfield	52	3	35,1		0	47	13,7	E
Acton	52	3	31,2		0	45	31,7	E
Beauchamp	52	3	34,4		0	37	20,2	E
Hedingham Castle	51	59	35,6		0	36	7,6	E
Ridgewell	52	2	18,8		0	32	12,1	E
Langham	51	57	51,6		0	57	28,1	E
Earles Colne	51	55	34,2		0	42	15,6	E
West Bergholt	51	55	0,1		0	50	13,3	E
Braxted	51	48	25,5		0	40	58,4	E
Kelvedon	51	50	5,5		0	41	33,0	E
Messing	51	50	12,5		0	45	2,5	E
East Thorp	51	51	33,2		0	46	28,4	E
Witham	51	53	34,4		0	38	6,1	E
Tarling	51	48	13,0		0	34	11,7	E
Willingale Spain	51	44	31,6		0	18	40,0	E
Braintree	51	52	33,7		0	32	57,5	E
Felstead	51	51	23,3		0	25	59,2	E
Great Leigh	51	48	41,8		0	31	7,8	E
Great Baddow	51	42	55,8		0	30	7,2	E
Chelmsford	51	44	5,8		0	28	19,7	E
Whittle	51	43	43,4		0	25	39,6	E
Roxwell	51	45	2,3		0	22	57,7	E
White Roding	51	47	48,2		0	15	50,8	E
Doddinghurst	51	40	1,8		0	17	49,4	E
Theydon Mount	51	40	18,0		0	9	31,1	E
Navestock Mill	51	38	52,2		0	15	55,8	E
Theydon Garnon	51	40	23,6		0	7	44,2	E
Havering	51	36	58,7		0	11	6,1	E
Cupola at Woodford	51	36	26,5		0	1	12,3	E
Ruins near Ilford	51	34	17,3		0	3	30,7	E
Hunsdon	51	47	40,8		0	3	23,5	E
Broxbourn	51	44	30,8		0	0	47,8	E
Harlow	51	46	54,4		0	5	38,4	E
Sabridgeworth	51	48	42,5		0	9	14,4	E
Bishop Stortford	51	52	13,4		0	9	30,5	E
Stanstead Mountfitchet	51	53	40,2		0	12	35,1	E
Farnham	51	54	4,4		0	9	7,0	E
Windmill, Meesden	51	58	18,5		0	5	4,9	E
Newport	51	59	2,5		0	12	50,6	E
Shudy Camps	52	4	24,2		0	21	49,9	E
Asbdon	52	2	54,7		0	18	17,6	E

West Parts of Kent.

Windmill, Sevenoaks	51	14	58,5		0	11	12,9	E
Chiddingstone	51	11	10,6		0	8	49,6	E
Station, Mount Sion	51	15	20,8		0	14	52,6	E
East Peckham	51	14	40,1		0	22	45,2	E
Tudeley	51	11	6,0		0	19	9,4	E
Seal Chart	51	16	13,6		0	15	35,3	E
Tunbridge	51	11	51,6		0	17	1,6	E
Otford Mount	51	18	55,3		0	12	25,3	E
Well Hill	51	21	9,8		0	8	55,3	E
Crayford	51	27	17,8		0	10	32,2	E
Ash	51	21	26,9		0	18	0,2	E
Bidborough	51	10	0,3		0	14	6,8	E
Station near Bidborough Church	51	10	4,0		0	13	44,3	E
Tree near Kibben's Cross	51	7	48,8		0	21	45,1	E
Cowden Steeple	51	7	34,2		0	6	9,9	E
Leigh Steeple	51	11	51,8		0	12	58,3	E
Ide Hill	51	14	40,3		0	7	43,9	E
Eatonbridge	51	10	6,0		0	4	3,3	E
Hadlow	51	13	23,4		0	20	22,3	E
Sundrich	51	16	27,7		0	8	8,7	E
Windmill, Ketson Common	51	22	27,5		0	1	59,6	E
Hayes Common Flagstaff	51	21	46,9		0	1	35,3	E

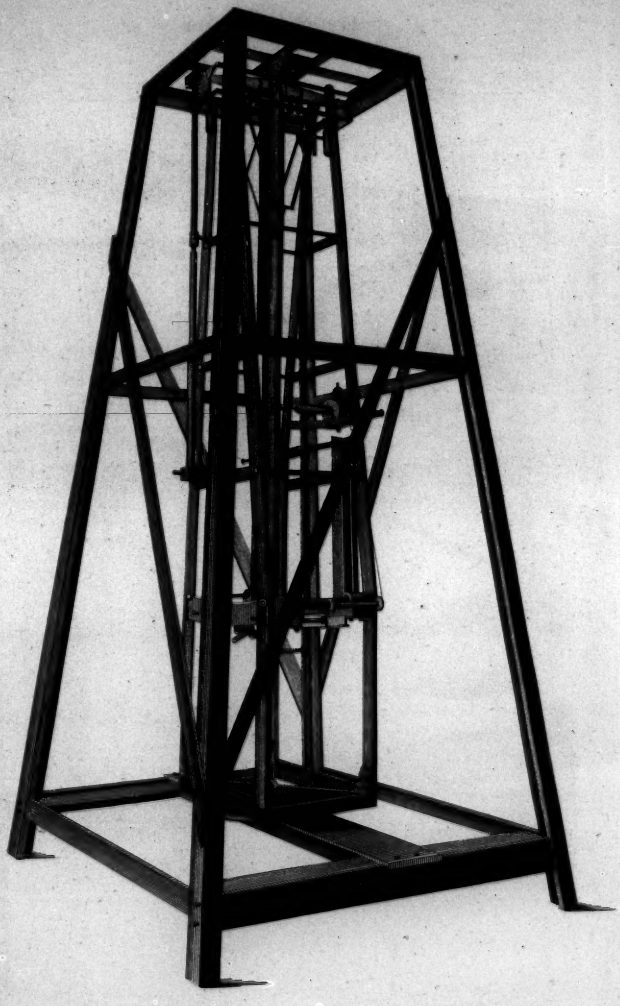
GENERAL VIEW of the ZENITH SECTOR.

Names of stations.	Latitudes.			Longitudes.			
	°	′	″	°	′	″	
Addington Common Flagstaff	51	21	30,1	0	3	6,6	E
Farnborough	51	21	20,4	0	5	53,2	E
St. Mary's Cray	51	23	42,9	0	6	57,3	E
Halstead -	51	19	57,3	0	7	43,6	E
Bromley -	51	24	17,8	0	0	51,9	E
Hayes - -	51	22	41,3	0	1	9,8	E
Lewisham -	51	27	20,2	0	0	52,7	W
Station, New Cross	51	28	5,1	0	2	29,3	W
Eastcombe Point	51	29	52,2	0	0	1,3	E
Woolwich -	51	29	34,6	0	5	38,2	E
Bexley -	51	26	24,8	0	9	17,3	E
Charlton Farm	51	23	27,0	0	4	10,9	E
Dartford Brent Mill -	51	26	26,1	0	14	10,5	E
Hartley -	51	22	34,5	0	19	2,3	E
Ridley -	51	21	4,9	0	19	13,3	E
Cliff Steeple -	51	27	43,1	0	29	50,2	E
Gravesend Steeple	51	27	39,2	0	22	9,7	E
Chalk Steeple	51	25	35,4	0	25	11,5	E
Guard Room, Lower Hope Point -	51	28	55,3	0	28	8,6	E
Flagstaff, Tilbury Fort -	51	27	8,8	0	22	37,4	E
Rainham -	51	21	46,5	0	36	30,7	E
Southfleet -	51	24	59,4	0	19	10,7	E
Shorn Mill -	51	24	54,7	0	25	41,3	E
Gillingham -	51	23	27,4	0	37	3,0	E
St. James's, Isle of Grain -	51	27	36,9	0	54	6,9	E
Friendsbury	51	25	29,0	0	30	18,4	E
Star Inn -	51	22	18,5	0	37	1,1	E
Upper Bell Inn	51	19	49,2	0	30	28,9	E
Upchurch -	51	22	36,1	0	38	49,2	E
Bobbing -	51	21	13,6	0	42	34,0	E
Frinstead -	51	17	3,9	0	42	37,9	E
Hoen Hill -	51	18	28,2	0	57	34,9	E
Stockbury -	51	19	27,6	0	38	55,3	E
Hucking -	51	17	37,6	0	38	38,3	E
East Church -	51	24	8,8	0	51	31,9	E
Milton -	51	21	20,3	0	44	21,0	E
Iwade -	51	23	39,5	0	43	24,4	E
Witchling -	51	16	8,4	0	44	36,8	E
Sheldwich -	51	16	31,6	0	52	51,4	E
Queenborough	51	25	3,4	0	44	36,5	E
St. Mary's -	51	27	34,4	0	53	40,1	E
Feversham -	51	19	2,3	0	53	35,7	E

In page 399, line 13, *for* G, *read g*.

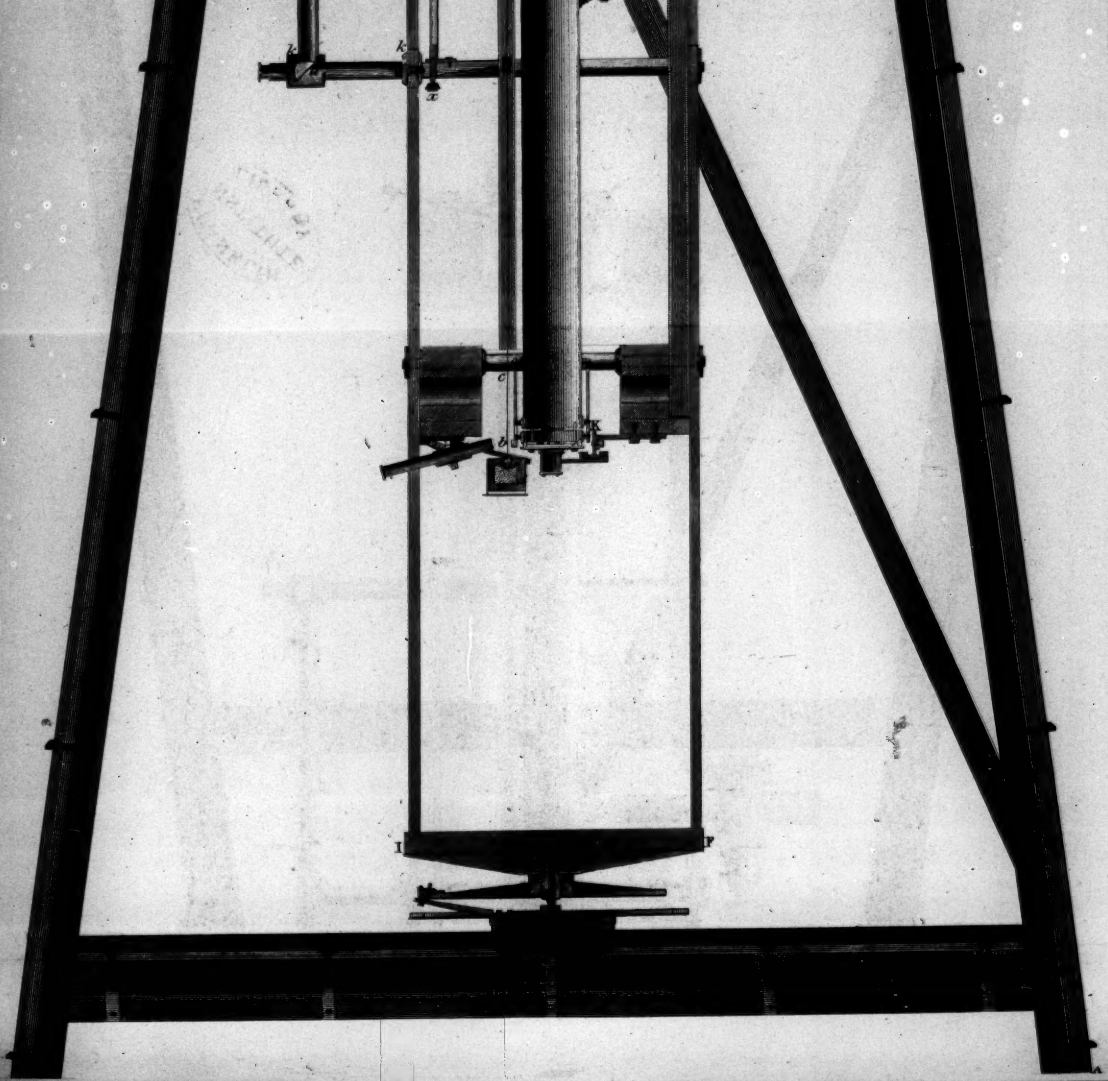
——— 415, lines 5 and 6 from the bottom, *for* 430 revolutions, *read* 436.

——— 468, line 3, *for* 45 divisions, *read* 405.

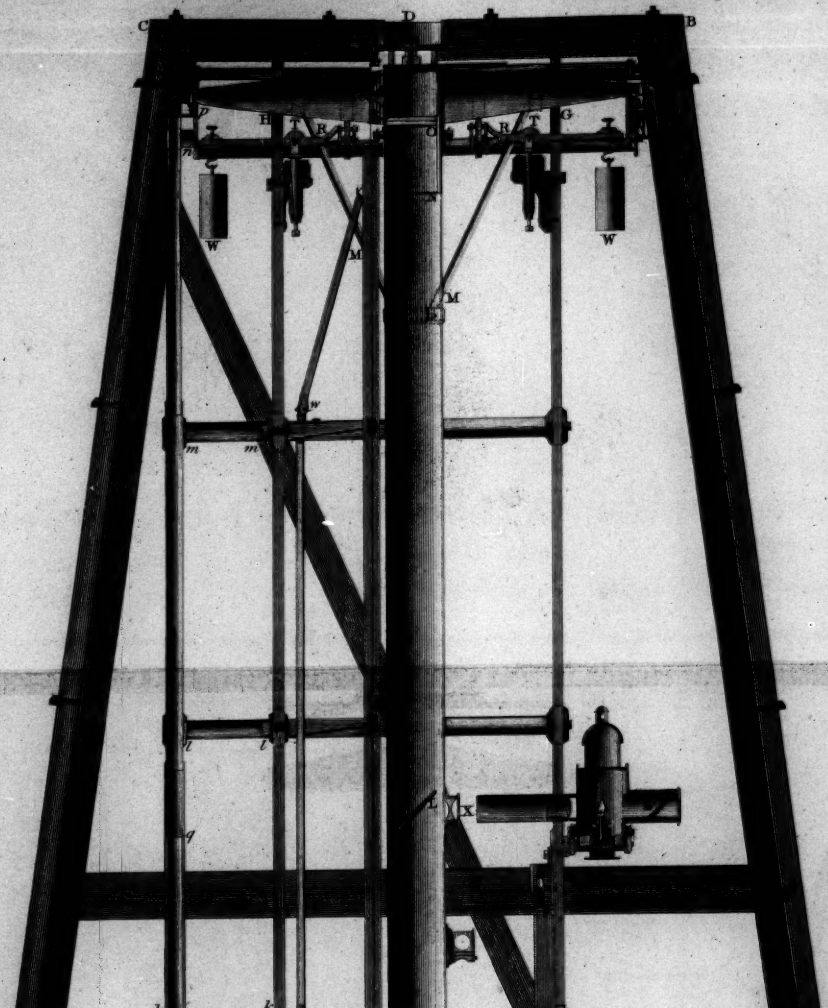


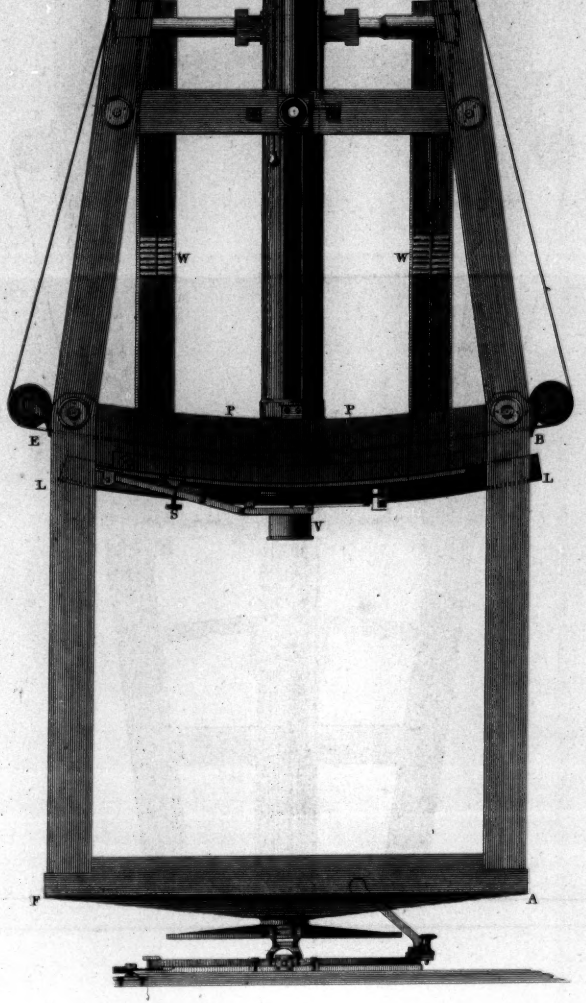
Basire sc.

GENERAL VIEW of the ZENITH SECTOR.

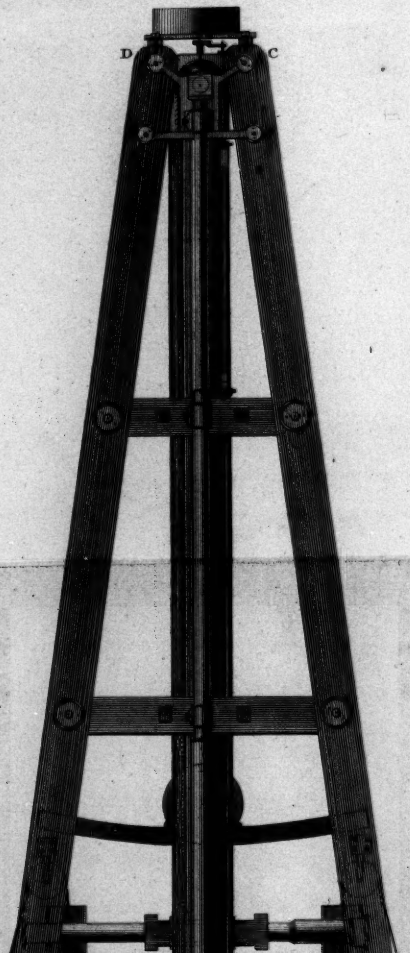

k
k
x
c
b
I
F

SECTION *of the* ZENITH SECTOR *through the Plane of its* AXIS.

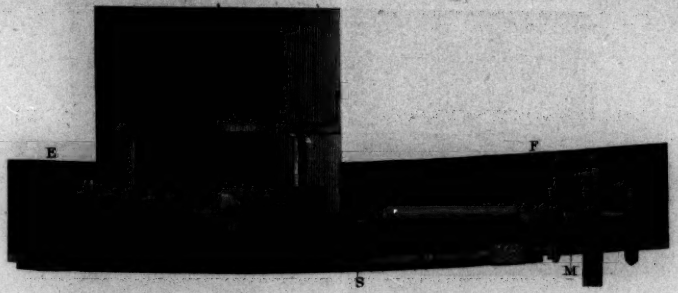



W
W
P
P
E
B
L
L
S
V
F
A

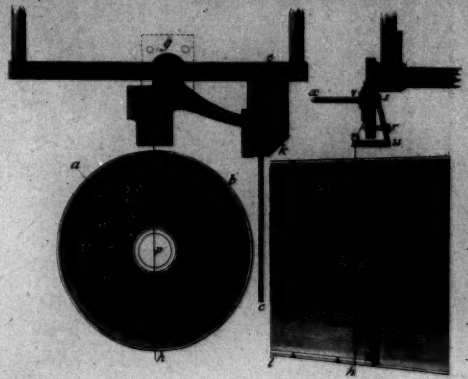
ELEVATION *of the Side of the Interior* ***FRAME*** *carrying the* **ZENITH SECTOR.**



Section *of the Bottom of the* Telescope, *with its* Micrometer Screw.



Section *of the* Diaphragm *Carrying the* Dot *also a* Section *of the* Axis *with the* Diaphragm.



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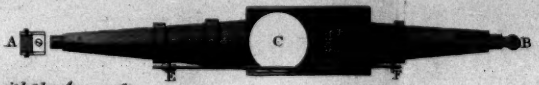
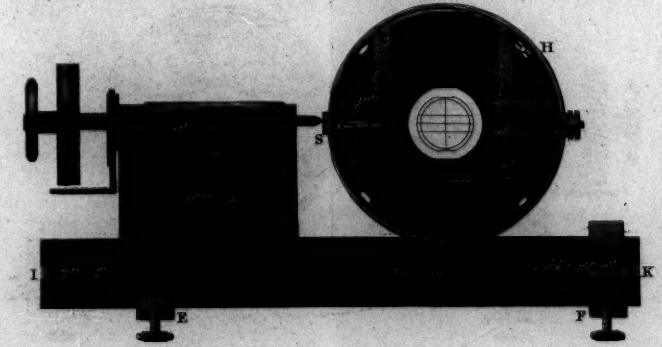
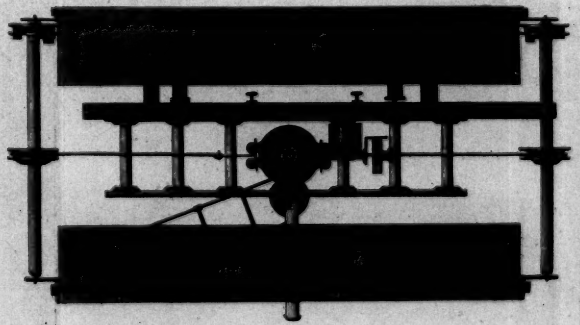
Horizontal View *of the Upper Part of the* Axis.

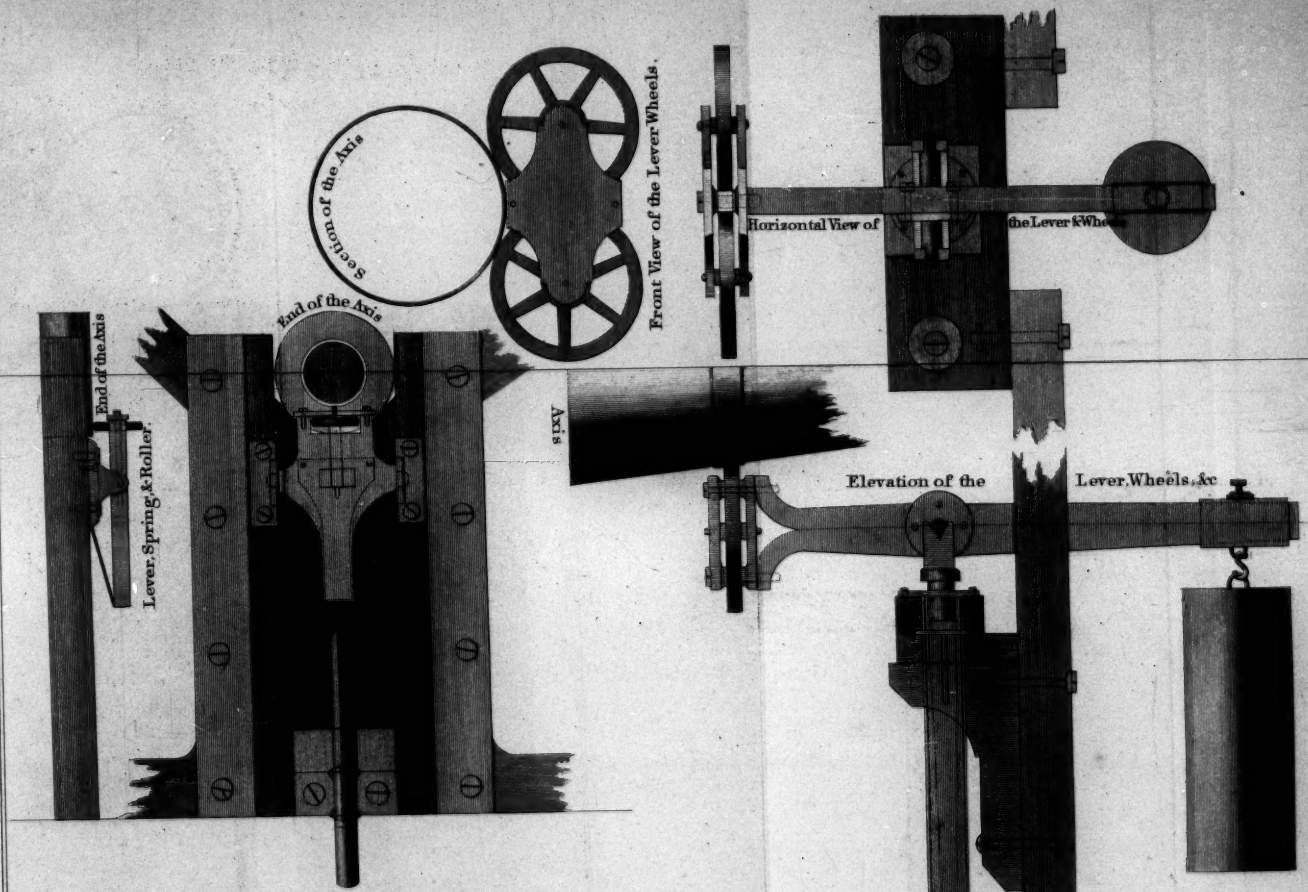


Horizontal View *of the End of the* Telescope, *with the Apparatus carrying the* Wires, *and also a view of its* Micrometer Screw.



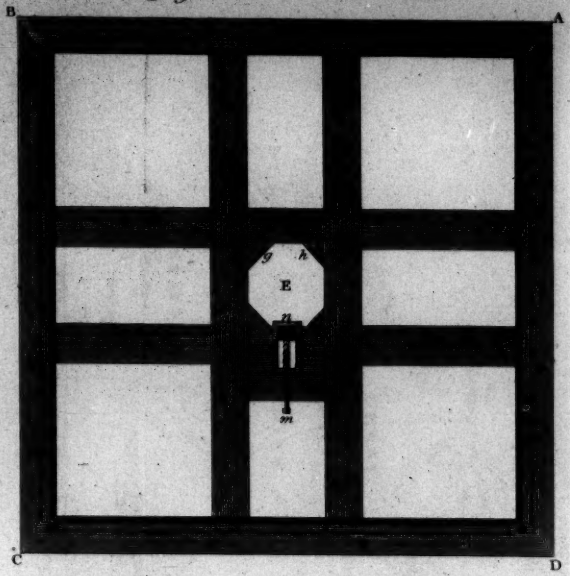
Horizontal View *of the* Axles, Pulleys *and* Arches.



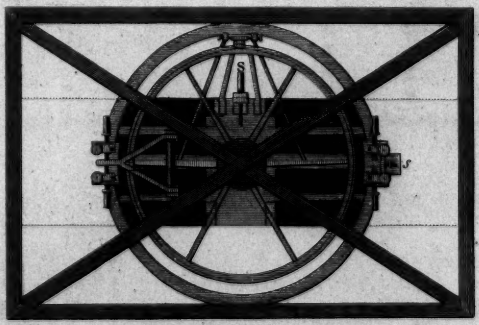


View of the *PLATE* carrying one of the Y s.

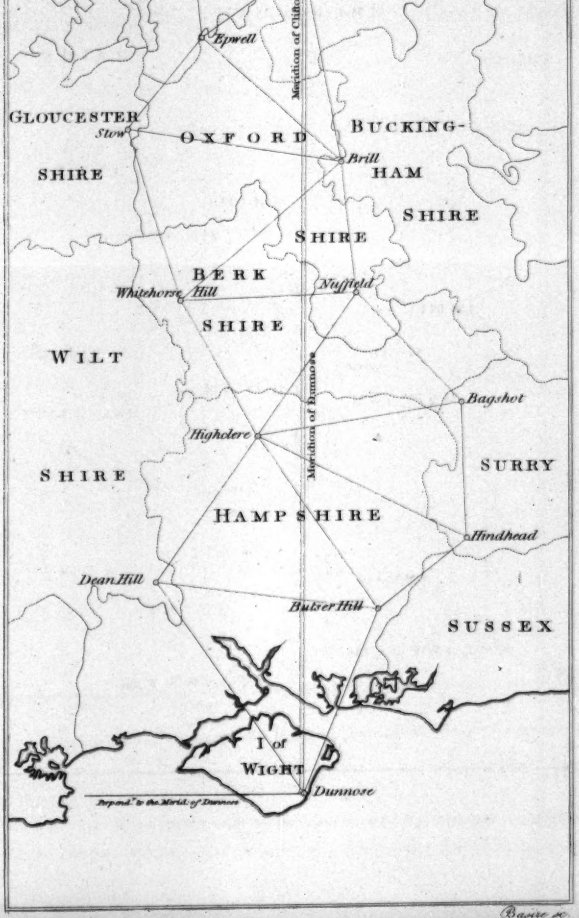
Top *of the External* Stand.



Bottom *of the Internal* Frame *resting on the* Azimuth Circle.



Barnes


Meridion of Clifton
Epwell
GLOUCESTER
SHIRE
Stow
OXFORD
SHIRE
Brill
BUCKING-
HAM
SHIRE
SHIRE
BERK
SHIRE
Whitehorse Hill
Nuffield
WILT
SHIRE
Meridion of Dunnose
Bagshot
Highclere
SURRY
SHIRE
HAMPSHIRE
Hindhead
Dean Hill
Butser Hill
SUSSEX
I of
WIGHT
Dunnose
Prepard. by the Marid. of Dunnose
Basire sc.

Philos. Trans. MDCCCIII. Plate XV. p. 508.

TRIANGLES *for ascertaining the* Meridional Distance *between* CLIFTON *and* DUNNOSE.

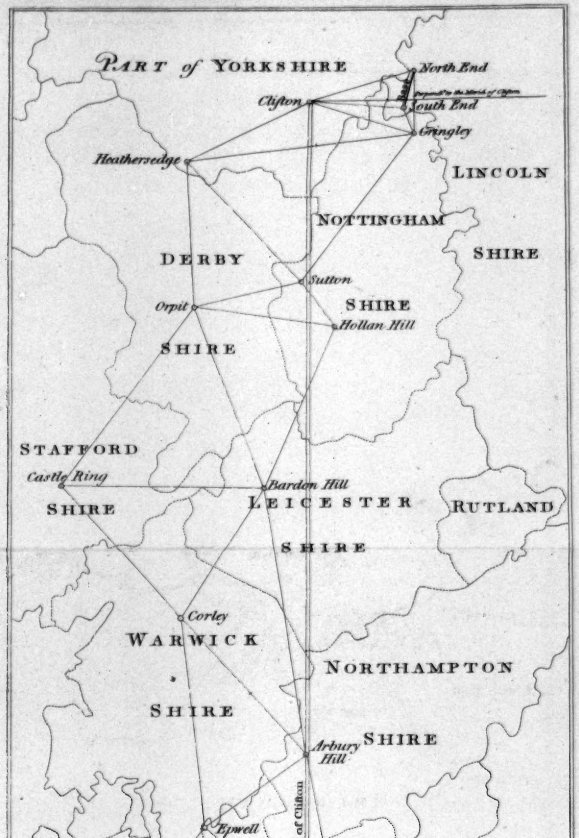
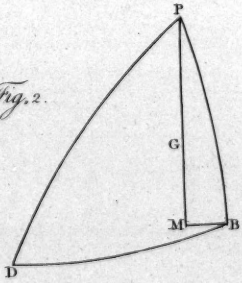


Fig. 1.

Fig. 2.



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	Transactions of the Royal Society of Edinburgh. Vol. V. Part II. 1802. 4°	The Royal Society of Edinburgh.
	Transactions of the Royal Irish Academy. Vol. VIII. Dublin, 1802. 4°	The Royal Irish Academy.
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	Analytical Institutions, by Donna Maria G. Agnesi; translated by the late Rev. John Colson. London, 1801. 2 Vols. 4°	The Rev. John Hellins, B. D. F. R. S.
	Specimens of British Minerals, selected from the Cabinet of P. Rashleigh. The Second Part. London, 1802. 4°	Philip Rashleigh, Esq. F. R. S.
	A General Atlas, published by Robert Wilkinson: Europe, Asia, Africa, France.	John Wilkinson; M. D. F. R. S.
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	Beiträge zur chemischen Kenntniss der Mineralkörper, von M. H. Klaproth. 3 Band. Berlin, 1802. 8°	Professor Klaproth, F. R. S.
	Bibliotheque Britannique. No. 153—158.	Professor Pictet, F. R. S.

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	Della Scoperta del nuovo Pianéta Cerere Ferdinandea. Palermo, 1802. 4°	M. Piazzi.
	An Account of the English Colony in New South Wales, by Lieut. Col. Collins. Vol. II. London, 1802. 4°	Lieut. Colonel Collins.
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	Considerations on the Substance of the Sun, by A. B. Woodward. Washington, 1801. 8°	Mr. Augustus B. Woodward.
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	Saggio di Esperienze sul Galvanismo, di Gio. Aldini. Bologna, 1802. 8°	Professor Aldini, of Bologna.
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	Selenotopographische Fragmente, von J. H. Schröter. 2 Theil. Gottingen, 1802. 4°	Dr. Schröter, F. R. S.
	Cours de Physique céleste, par J. H. Hassenfratz. Paris, 1803. 8°	M. Hassenfratz.
	The Anniversary Sermon of the Royal Humane Society, by R. Valpy. London, 1802. 8°	The Rev. R. Valpy, D. D.
Dec. 9.	Journals of the Royal Institution of Great Britain. No. 13.	The Managers of the Royal Institution.
	Analyse detaillée de différentes Questions qui se rapportent au Mouvement d'un Corps sollicité par des Puissances quelconques, par R. Prony. Paris, An. 9. 4°	M. Prony, de l'Institut de France.
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	Recueil en Ordre alphabetique de Noms de Minéralogie, par le Prince D. de Gallizin. Brunswick, 1802. fol.	Prince Dimitri de Gallizin, F. R. S.
	Meteorological Journal kept at Cumberland House,	Joseph Colen, Esq.

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	The Philosophical Magazine, by A. Tilloch. No. 54.	Mr. Alexander Tilloch.
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	Histoire du Canal du Midi, connu précédemment sous le Nom du Canal de Languedoc, par F. Andreossy. Paris, An. 8. 8°	———
	Campagne sur le Mein et la Rednitz, de l'Armée Gallo Batave aux Ordres du Général Augereau. Paris, 1802. 8°	———
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Jan. 13.	A Journal of Natural Philosophy, by W. Nicholson. No. 13.	Mr. William Nicholson.
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	J. E. Bode von dem neuen achten Hauptplaneten des Sonnen Systems. Berlin, 1802. 8°	———
	Osservazioni su i Punti fondamentali della Dottrina del Citt. Quatremere Disjonval, rapporto all'Origine delle Arti, de'Culti, del Linguaggio, e della Scrittura, del Citt. L. Bossi. Torino, An. 11. 8°	Sig. Luigi Bossi.

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